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16. ABSTRACT
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Blistering was a problem on both installations. The blisters usually broke and spalled, decreasing the effectiveness of the overlay as a waterproof membrane.

The overlays applied as seal coats near Sacramento were effective in providing nonskid surface but the trowelled overlays varied from poor to marginal. Skid resistance of overlays in the mountains reached a value nearly that of the adjoining concrete within one year which in some cases was below desirable values.

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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, *Governor*

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
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Research Report
P. W. O. 635121

June, 1969

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

THIN RESINOUS AND AGGREGATE OVERLAYS

ON PORTLAND CEMENT CONCRETE

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Assisted by
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John P. Bowden
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Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

69-05

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KEY WORDS: Epoxy resins, polyesters, overlay course, seal coats, coefficient of friction, field tests, laboratory tests.

ACKNOWLEDGMENT

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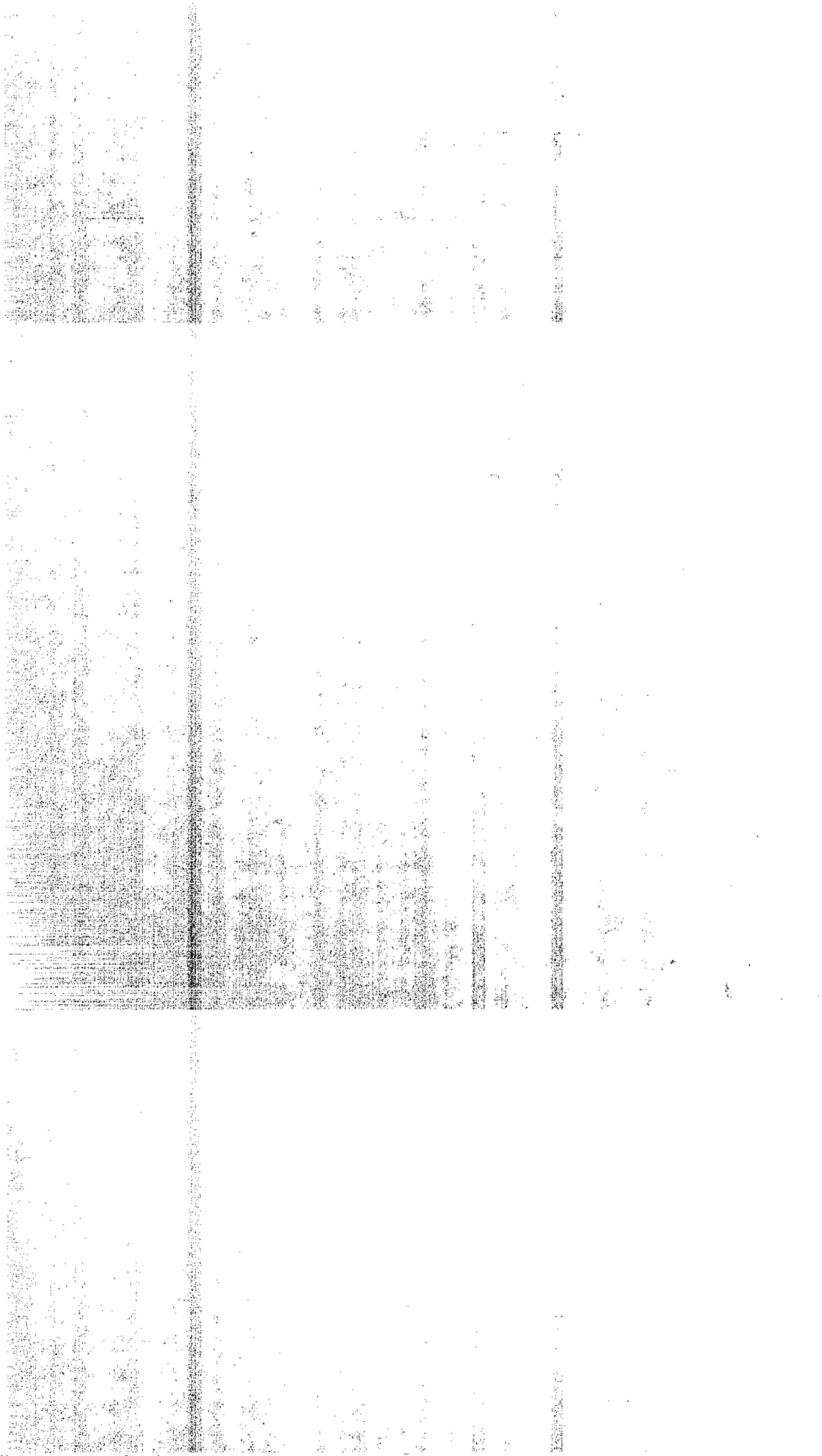
The opinions, findings and conclusions expressed in this report are those of the authors and are not necessarily those held by the Bureau of Public Roads.

No part of this report is to be used for advertising or promotional purposes.

In this report it is understood that the products mentioned by trade name may be replaced by other formulations having the same physical and chemical properties. Trade names given in this report do not in any way constitute endorsement of such materials to the exclusion of equal products.

TABLE OF CONTENTS



THIN RESINOUS AND AGGREGATE OVERLAYS

OF PORTLAND CEMENT CONCRETE

INTRODUCTION

This is a final report on the investigation of the resinous binders for use in overlays over portland cement concrete under this project. Future work of this type will be done under Federal Research Project 635150 "Formulation and Evaluation of New Adhesives for Highway Use". Fifteen different formulations of flexibilized resinous binders combined with a suitable aggregate were tested for durability and skid resistance. The final aggregate-binder color of most sections was approximately that of concrete. Wearing surfaces of modified epoxy and polyester resins, using fine sand as an aggregate, were applied to portland cement concrete for evaluation as seal coats and as a trowelled mortar topping. The overlays were tested under two different climatic conditions.

The first application, placed in late spring of 1965 was near Sacramento on Highway 99 where summer maximum temperatures average about 95°F (occasional highs of 110°F) and the winter minimum seldom reaches freezing. The second application placed in late spring of 1966 was on Interstate Route 80, at Kingvale, on a 5% upgrade, at an elevation of approximately 6,000 feet. Both overlays are subjected to high traffic density. The second installation, in the mountains, is subjected to extreme temperature changes (0 - 105°F) and to wear from chains and snowplows during the winter months. Chains are required whenever there is danger of snow or ice in this area. Snow tires or studded tires are not permitted in lieu of chains.

The installations were intended primarily to evaluate binders with a common aggregate applied at a uniform thickness. However, some tests were included to determine the effectiveness of different thicknesses of overlay, different methods of application and different types of aggregate.

Extensive laboratory tests on all formulations were performed in hopes of obtaining a correlation between laboratory and field performance.

CONCLUSIONS

It is possible to formulate many binders for seal coat application which will give a service life for an estimated five years or greater when not subjected to chain and snowplow action.

The Valley installation in the truck lanes of a six lane freeway, with an average annual daily traffic of 38,000 vehicles, has been generally satisfactory as a wearing course after nearly four years service except for one section of Guardkote 250 applied as a seal coat. This section is completely worn out in the wheel tracks (see Figure 8). Since this binder appeared to be equal or perhaps superior by laboratory tests, it appears that it will be difficult to prove field durability by existing laboratory tests alone. This same binder used in a trowelled mortar section has proven durable.

Color change has occurred with some binders and extensive pitting has resulted from blisters which formed at the time of application and later broke under traffic. Some sections are also showing very slight signs of wear as well as considerable loss of sand. The coefficient of friction of the valley seal coats using rounded sand decreased from the original value of about 0.40 to about 0.30 in the wheel track as measured by the California skid tester. A more angular sand has maintained better skid resistance to date. It was difficult to consistently obtain adequate coefficient of friction with the trowelled mortar overlays.

The mountain installation in truck lanes of a four lane freeway, with an annual average daily traffic of 10,000 vehicles, showed that the polyester sections without an epoxy primer failed very quickly due to poor bond to the concrete. However, when applied over an epoxy primer, a 1/4" thick, three layer application of a polyester binder supplied by Reichhold Chemical, Inc. is showing good durability after nearly three years of service. The epoxy primer in this section blistered and this has caused some spalling over the blisters.

A thin overlay of 1/8" to 3/16", using the best epoxy binders tested, would be expected to have a service life of no more than one year under heavy chain and snowplow action. Two "double overlay" epoxy sections of about 1/4" in thickness gave a service life of approximately two years. While some wear occurred from the surface, especially with Guardkote 140, most of the failure of the overlay is due to the lack of adhesion caused by the presence of water during prolonged periods. This lack of adhesion was probably caused by excessive modification of the epoxy resin to achieve low temperature stress relaxation.

Two experimental formulations, AC 51 and AC 82, have been recently developed which have higher compressive strength, are rapid curing and have better adhesive and cohesive strength. However, it may be necessary to further modify the AC 82 to provide better adhesion and cohesion by reducing the oil extender. Preliminary tests indicate that these formulations will withstand freeze-thaw conditions. AC 51, with a minimum of oil modification has a compressive strength of about 12,000 lbs/in^2.

Epoxy overlays in the mountains were polished by chain and snowplow action which lowered the coefficient of friction from .25 to .16.

BACKGROUND

The use of a relatively rigid epoxy as a binder for a wearing surface gives excellent adhesion to concrete, very high structural strength, and with proper aggregate provides a durable wearing surface under some conditions. This type of application has been used in California for about 14 years. However, due to the large difference between the coefficient of expansion of portland cement concrete and that of the epoxy overlay, even when highly filled with sand, failure can occur where freezing is encountered. The failure is usually in the form of shearing of concrete under the overlay.

In evaluating epoxy resins designed to avoid this type of failure, we tested a coal-tar modified epoxy, Guardkote 140, in 1960 and found it to have the ability to yield or "creep" under stress at low temperature, thus avoiding failure. California Test Method 419 is now used to evaluate this property. This type of material has a longer field service history than any other highly flexibilized epoxy. The black color of this material is sometimes objectionable from an aesthetic viewpoint and there has been considerable interest in developing color stable binders which will give an overlay which is nearly concrete in color.

On this project no material was applied thicker than about 1/4"; however, several of the binders tested have been used successfully in thick sections as epoxy mortar and epoxy concretes for patching spalled areas in concrete where high compressive strengths are not required.

MATERIAL SELECTION AND FORMULATION

Binders

The binders selected fell into three categories:

1. Epoxy resins modified with light colored extenders including pigmented, nonpigmented, compatible and non-compatible systems.

2. Epoxy resins modified with dark colored extenders.

3. Polyesters.

A key listing manufacturers of binders is on Page 7.

All of the binders were formulated and furnished by industry except 1 and 9. No. 1, an epoxy type binder was formulated by the Materials and Research Laboratory and a specification written previous to this project (see Specification 1R413a). This epoxy was extended and flexibilized by the use of 50 phr (parts per 100 of resin) of an aromatic oil (Mobilsol 66). An epoxy resin was used containing 10 to 12% butyl glycidyl ether as a reactive diluent which gives a viscosity of 5 to 7 poise. The low viscosity of this system when used with nonyl phenol and amino ethyl piperazine for curing and flexibilizing permitted the addition of filler to control flow and give proper color in individual components and when mixed. A formula with one black component and one white component mixed in a 1:1 by volume ratio before use helps the applicator determine when the material is properly mixed. This is very important when the adhesive is mixed by hand for small repairs. The use of the aromatic oil produced satisfactory properties in general but was subject to color change as were two other formulations placed in the first application. The gray binder turned brown under the action of sunlight after a few weeks exposure.

In order to achieve color stability we searched for a different oil modifier which would be color stable, have a low viscosity, and a high distillation range. Several oils were considered and one was selected which was expected to be most color stable based on its chemical composition. The reactivity of the oil with sulfuric acid was also used as a secondary check on the stability of the oil. The oil selected was a synthetic alkyl benzene (Chevron Alkylate 31) with the alkyl side chain having an average length of thirteen carbon atoms. This oil was not sufficiently aromatic to be compatible without using a coupling agent such as dinonyl phenol. It was necessary to use this coupling agent in a one-to-one ratio by weight with the oil to achieve a compatible mix. Very little, if any, oil exudation has been experienced with this formula. The total quantity of the dinonyl phenol and oil in the final formulation used was 80 phr. This binder (No. 9), designated Specification 66-F-46 (now 681-80-46) appeared to have most of the desirable properties of 1R413a and in addition had excellent color stability.

One interesting phase of the development of 66-F-46 was the control of the wetting properties. Early tests of the binder, when mixed with an aggregate, showed considerable air entrappment in both thin overlays and 2" x 4" compression cylinders. The addition of a very small percentage (25 ppm) of a silicone eliminated this difficulty, and increased the density of the compacted mix by about 8%. The compressive strength increased from an average of about 1400 psi to 1900 psi. Thus, 25 ppm of silicone appeared sufficient to prevent the entrappment of excessive air. However, higher amounts had little effect on air content and did not appreciably raise or lower the compressive strength even when used in quantities up to 20,000 ppm. A value of 100 ppm was chosen for use in the formulation.

Binders were supplied by several major adhesive formulators showing an interest in this program. A total of 9 oil or Thiokol-modified epoxies, three polyester and three dark modified epoxies were applied. Polyurethane based resins were considered but none were included in this evaluation because of cost, color, or application difficulties. Unfortunately, no asphaltic or modified asphaltic binders were used, although a comparison, especially with a highly rubberized asphalt, would have been of interest.

BINDER SUPPLIERS AND LOCATION OF TEST SECTION

OIL OR THIOKOL MODIFIED

	Binder	Test Section Location	Section
1	State 1R413a (similar to latter State Spec. 682-80-45)	Sacramento	1
2	Adhesive Engineering 1064-3	Sacramento	2
3	Thiokol, P. E. System	Sacramento	3
4	H. B. Fuller 7121	Sacramento	5
5	H. B. Fuller 7121	Kingvale	13
6	Shell Guardkote 250 (noncompatible)	Sacramento	6 a,b
7	Shell Guardkote 250 (noncompatible)	Kingvale	12
8	Furane 8412	Kingvale	11
9	State Spec. 66-F-46 (now 681-80-46)	Kingvale	14 a,b,c,d
10	Adhesive Engineering 1115 (noncomp.)	Kingvale	15
11	Adhesive Engineering 1064-23	Kingvale	16
	Polyester		
12	Reichhold Polylite 98-520	Sacramento	4
13	Reichhold Polylite 31-830	Kingvale	9, 10
14	Chevron Polyester, Prime CX 440 Overlay CX 439	Kingvale	8
	Bitumel or Other Dark Colored Material		
15	Shell Guardkote 140	Kingvale	17 a,b
16	Shell Guardkote 140	Sacramento	7 a,b,c,d
17	Reichhold Modified Epoxy	Kingvale	18
18	Edoco Ed-Oxy	Kingvale	19

Materials were those available from the various suppliers three to four years ago. Formulations may have changed even though the product name and number may be the same.

LABORATORY TESTS

The following laboratory tests were performed.

1. Viscosity
2. Tensile and elongation after 7 days cure at 25°C.
3. Tensile and elongation after 7 days cure at 25°C + 14 days at 70°C.
4. Tensile and elongation after 7 days at 25°C + 100 hours in Atlas Fadometer.
5. Reflectance, original and after 100 hours in Atlas Fadometer.
6. Water absorption
7. Tensile Adhesion
8. Freeze-Thaw
9. Volatile Distillation
10. Gel time
11. Compressive Strength
12. Shore D hardness during heat aging at 105°C for 42 hours.
13. Weight loss during heat aging at 70°C and 105°C for 42 hours.
14. Low temperature creep.
15. Abrasion resistance of aggregates.

DISCUSSION OF LABORATORY TEST RESULTS

Average test results are given for each of the determinations. The physical properties of the binders are given on Pages 5 through 9 in the Appendix.

Test 1 Viscosity

The viscosity of the individual components varied from 4 to 6160 poise. The lower viscosity materials would be easier to mix and spread by hand or spray. However, too low viscosity or lack of thixotropy would result in excessive flow on a slope.

Test 2 Tensile Strength and Elongation After 7 Days Cure at 25°C

The elongation and creep of binder 3 (Thiokol P. E. System) were lowest of any sample tested. It was also the only binder to fail the laboratory freeze-thaw test.

Test 3 Tensile Strength and Elongation After 7 Days Cure at 25°C and After an Additional 14 Days at 70°C

Tensile strength varied from about 400 psi to over 5,000 psi. Generally the test strength increased and the elongation decreased with the additional 14 days cure at 70°C. However, with binders 3 and perhaps 6 (Guardkote 250) the reverse was true.

Test 4 Tensile and Elongation After 7 Days and 100 Hours in Atlas Fadometer

The only significant observation here was the effect on binder 3 showing the drop in tensile strength and increase in elongation with additional heating.

Test 5 Reflectance, Original and After 100 Hours in Fadometer

This test was intended to measure the color stability of the binders using completely instrumental methods. Reflectance was measured before and after the exposure in the Fadometer and the percent change computed. Generally the samples that showed less than 20% change in the Fadometer showed little change on the roadway. Probably any material that is color stable by this test would also be color stable on the road.

Test 6 Water Absorption

Results varied from 0.17 to 2.1%. Binder 6, with one of the lower water absorption values, was the only material to wear through in the valley installation.

Test 7 Tensile Adhesion

All failures were in the concrete except for the polyester. All the epoxy formulations have initial adhesion above 200 psi which is a usual specification value for this test. Tests were run without priming the concrete surface.

Test 8 Freeze-Thaw

All materials tested passed the freeze-thaw test except binder 3. If this material had been heat cured it would possibly have passed this test.

Test 9 Volatile Distillation

The high value on component A of binders 1 and 9 was due to the presence of butyl glycidyl ether as a reactive diluent. This high value would be cause for rejection under many specifications as indicating solvent adulteration. A flash point test would detect adulteration with solvents and not prohibit the use of this type of reactive diluent. See Test 16, Page 10 in the Appendix.

Test 10 Gel Time

This test gives an approximate indication of the rate of set of the material. Results varied from 15 to 110 minutes. It would be somewhat unreliable in determining set time in relatively thin layers. Under field conditions black materials will absorb more heat radiation than colorless or light gray materials. However, application of binder 18 (Edoco Ed-Oxy; gel time 110 minutes) at Kingvale, with air temperatures of about 60°F, cured slowly due to the long set time even though the binder was black and the sun was shining.

Test 11 Compressive Strengths

This test was included primarily to evaluate the suitability of the materials for use in thick sections, a value of about 1500 psi being required. Values of 6,000 to 8,000 psi or higher might be required for use on such repairs as expansion dams where the edge of the repair is subject to impact by traffic and not supported by a form. Binder 3 would likely have shown a much lower compressive strength after heat aging.

Test 12 Shore D Hardness During Heat Aging at 150°C for 42 Hours

While the determination of the hardness by means of the Shore D Durometer was probably not the best means of following changes in hardness during heat aging, some conclusions could be drawn: (1) There was little change in the polyester resin 12 and 13 (Reichhold Polylite). (2) Softening after heat aging was dramatically shown with binder 3. (3) Binder 6 (Guardkote 250) showed the least tendency to harden of any of the modified epoxy resins which would appear to be a desirable property. This, however, was the first epoxy to show failure in the valley installation.

Test 13 and 13A Weight Loss During Heat Aging at 70°C and 105°C For 42 Hours

While the magnitude of loss was greater at 150°C than at 70°C, the order from low to high heat loss was generally the same at both temperatures.

Test 14 Low Temperature Creep

The creep test was devised to measure the ability of a binder to relieve stress at low temperatures. Binder 3 failed the freeze-thaw test and also had the lowest creep value of any of the binders. The coal-tar epoxy resin binder systems generally have a creep value of about .020" at 7 days. Most of the modified epoxies are above this value.

Test 15 Abrasion Tests on Aggregates Using a Common Binder

A coal-tar epoxy was used as the binder for this test. Of the aggregates tested, ratings from lowest loss to highest loss were silicon carbide, 10-20 mesh gopher sand, 8-12 mesh Bear River sand and 12 mesh garnet.

Test 16 Flash Point of an Epoxy Resin and Xylene

The results of this test would indicate the possibility of controlling the amount of solvent to less than 2% in the epoxy component by a flash point determination. The distillation test, often used for detecting solvents in the individual components, distills over the reactive diluent butyl glycidyl ether. When cured, the weight loss with heating of an epoxy with this diluent is as low as most epoxy resin systems passing the distillation test.

FIELD APPLICATION

A Broyhill unit for mixing and spraying was used to apply several of the binders on the Sacramento installation. Others were placed by hand with rollers or screeds and two with trowels to spread material from a mortar mixer. Due to the difficulty in applying short sections with a Broyhill, all sections on the Kingvale installation were placed by hand with screeds or other hand devices. No mortar type sections were applied at Kingvale because of the long cure time required by low pavement temperatures.

Aggregates on all seal coat sections were applied by hand shovel, either from a truck or from road level. In all seal coat overlays, excess sand was applied and then the excess loose sand was removed with a sweeper before the road was opened to traffic.

During the Sacramento application considerable blistering occurred as several of the binders were curing. Some of the blisters were broken and examined. There was a thin layer of epoxy and some sand still in contact with the pavement, but most of the overlay or trowel section was still on the top surface of the blister. The blisters in the trowelled mortar section were about 2" in diameter while the blisters in the seal coats were about 3/4" in diameter.

Most of the seal coat applications were placed at the rate of 3 lbs/yd^2 of binder giving an average binder thickness of about 1/16". The unfinished surface was between 1/8" to 3/16" after the sand had been applied. The trowelled sections, three of the four polyester sections, and two short epoxy sections at Kingvale were placed about 1/4" thick. The trowelled section was placed in one application, the thick epoxy section in two applications and thick polyester section in three applications. The Thiokol P. E. seal coat application was made at the rate of 1-1/2 lbs/yd^2 of binder.

DISCUSSION OF FIELD TEST RESULTS

Test 17 Field Tensile Test - Sacramento Installation

The values for tensile adhesion after 39 months were generally higher than those after 25 months. The values at 25 months were run in early summer and the overlay may have been affected by moisture under the concrete. While the value for the Reichhold polyester was high, the failure was still 100% in adhesion to the concrete.

Test 17 Field Tensile Test - Kingvale Installation

The first tests were performed in late summer and gave values averaging about 225 psi. When tensile tests were performed in the spring after 12 months of service the values dropped to about one third or less of the original value. However, in the fall, after 28 months service, the average value was nearly as high as the original. The varying moisture content under the overlay is believed responsible for the change.

Test 18 Skid Resistance - Sacramento Installation

The original skid resistance values for all the seal coats were about .40. The Bear River sand maintained a higher value than the more rounded gopher sand especially between the wheel tracks. The 10-20 gopher sand decreased to about .30 after 3 years of service and the 20-40 gopher sand was somewhat lower. The trowelled sections also had lower values, one being marginal and the other below accepted minimums.

GENERAL DISCUSSION

The cost of applying a seal coat type overlay would vary from $3.00 to about $8.00 a square yard depending on the size, location and condition of the surface to be covered. Because this is a very expensive type of repair this study was undertaken to evaluate the performance of different binders available. This research has shown that many binder systems can provide a durable wearing surface when subjected to high density traffic where chains and snowplow action are not encountered. At Kingvale, however, a single seal coat application of all binders tested showed considerable wear after one year. (See field test results Page 13 and Figures 9 through 15.)

There are certainly other field conditions, not investigated, which would be less severe than those at Kingvale but more severe than in the valley installation. These might be areas where there is higher traffic density, areas where snow tires rather than chains are used, application on structures where considerable flexing is encountered or installation in areas where there is higher rainfall.

Both the Sacramento and Kingvale applications were placed over pavement on grade. Since much repair work is often on bridge decks, this choice was a compromise in order to have a uniform test section with identical traffic for a 15' to 45' length for each test section. Therefore, results of these tests may not be applicable to overlays of bridge decks. It would seem possible that:

1. The flexing of the bridge deck might effect the performance of an overlay.

2. The lower moisture content of bridge deck concrete might affect the frequency of blistering.

3. The surface of the concrete on grade may be of a different texture and quality than a bridge deck.

The failure of the overlays in the mountains was due more to adhesive failure than wear despite the extreme abrasion from traffic. This was shown by the ease with which the overlays could be delaminated when wet during the winter and by the low tensile tests in the spring. It is probable that the epoxy binders in the Kingvale installation were over flexibilized with a resulting loss of adhesion during the winter.

Binders No. 1 (1R413) and No. 9 (681-80-46) were applied by Maintenance forces on a bridge at Kingvale after Installation No. 2 was completed. The performance of these two binders was identical, each showing considerable wear after a very severe winter. Binder No. 1 (1R413) has been reformulated as 682-80-45 to give better application properties when used in a Broyhill machine. The reactive diluent was changed to avoid coking.

The annual average daily traffic for the Sacramento Valley installation is about 38,000 vehicles for six lanes, both directions. This is considerably less than the Oakland-San Francisco Bay Bridge which has a count of about 150,000 vehicles for ten lanes. This structure has a Guardkote 140 seal coat which has been generally satisfactory for about five years. For comparison, a typical count for a ten lane freeway in a very high density area would be 230,000 vehicles (Interstate Route 10) in Los Angeles.

The Kingvale area has a traffic count of 10,000 vehicles for four lanes. The rapid wear in this area is due to the chains and snowplows during the winter months. A high percentage of the traffic at both test sites in the lanes used for the overlays was truck traffic.

The loss of sand in the overlays in the Sacramento Valley is a matter of concern and has been noted first in recent inspections. The loss is generally greater in the oil modified systems and less in the Thiokol modified, polyester, and Guardkote 140 systems. So far the skid resistance values seems to be relatively unaffected by the aggregate loss. The two important factors in this loss would appear to be the type of aggregate both in regard to chemical composition and shape; and the type of extender used in the binder. This will be investigated further in the future.

Insufficient data is available to adequately evaluate aggregate retention in mountain installation, however, chain and snowplow action soon abrade the surface to the level of the binder.

Two experimental epoxy formulations AC 51 and AC 82 based on a polymercaptan curing agent (attached) have been developed under Federal Research Project 635150 which have higher compressive strengths than most flexibilized systems. They also have a rapid rate of cure at low temperatures, approximately 4 to 8 times as fast as the conventional polyamine or polyamide curing systems. AC 51 is rigid, has a relatively short work life, and is not designed primarily for overlay work. Both of these adhesives have a low creep as measured by California Test Method 419 and would normally not be expected to be suitable for use in freeze-thaw environments. The coefficient of thermal expansion, especially of AC 51, is less than other epoxy systems tested and may be responsible for this behavior.

Neither AC 51 nor AC 82 rupture concrete on freeze-thaw cycling in the laboratory test and therefore further work is scheduled for laboratory and field testing of these adhesives for overlay and other repair work. Further field work will also be done with the polyester system (binder No. 13) over an epoxy primer.

The skid resistance of the overlays at Kingvale has not been encouraging since they are soon worn to the extent that they have about the same coefficient of friction as the adjacent concrete. The durable polyester (section 10) at Kingvale had a lower coefficient of friction than its "control" but was similar to the epoxy sections in the same area. Due to the difficulties of obtaining accurate readings below a value of .20, the significance of the slightly lower values for the polyester section has not been established. It would appear reasonable that this section might be polished to a greater extent by chain action due to the age of this overlay as compared to the epoxy sections.

Blistering was encountered at both test sites (refer to photographs and Charts 3 and 4). Many explanations have been offered for this phenomenon. It has been attributed to moisture vapor traveling upward through capillaries in the concrete. The temperature and the direction of temperature change during cure also seem to be factors. Solvent contamination was shown to cause or increase blistering on the Sacramento installation. Also, the rate of cure of the adhesive has been suggested as a contributing cause.

A resinous overlay would frequently not give a completely waterproof surface because of excessive wear, broken blisters, or burn through by road flares. The size and shape of the aggregate may also influence the permeability of the resinous overlay.

APPENDIX

CHART 1

DIAGRAM OF OVERLAYS AT SACRAMENTO

(NOT TO SCALE)

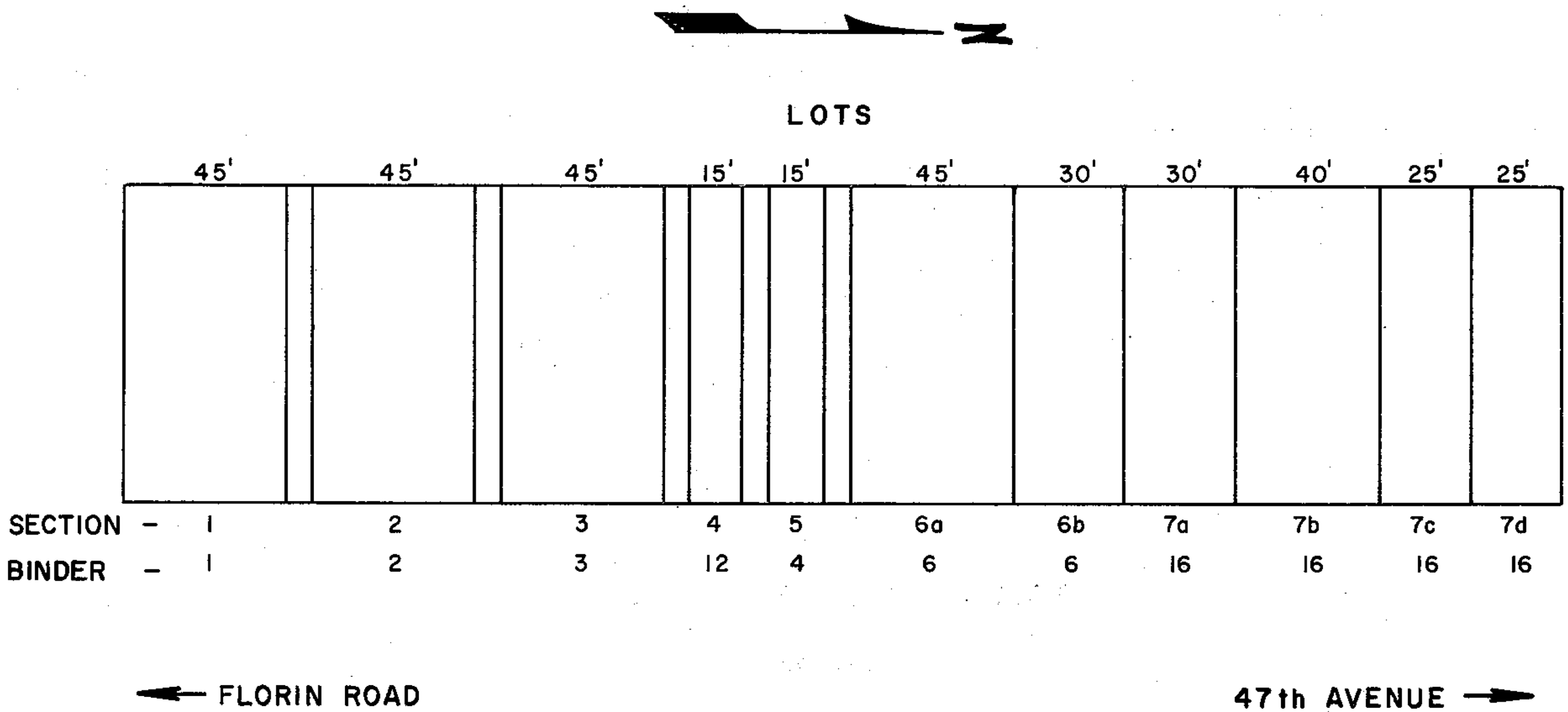


CHART 2

DIAGRAM OF OVERLAYS AT KINGVALE

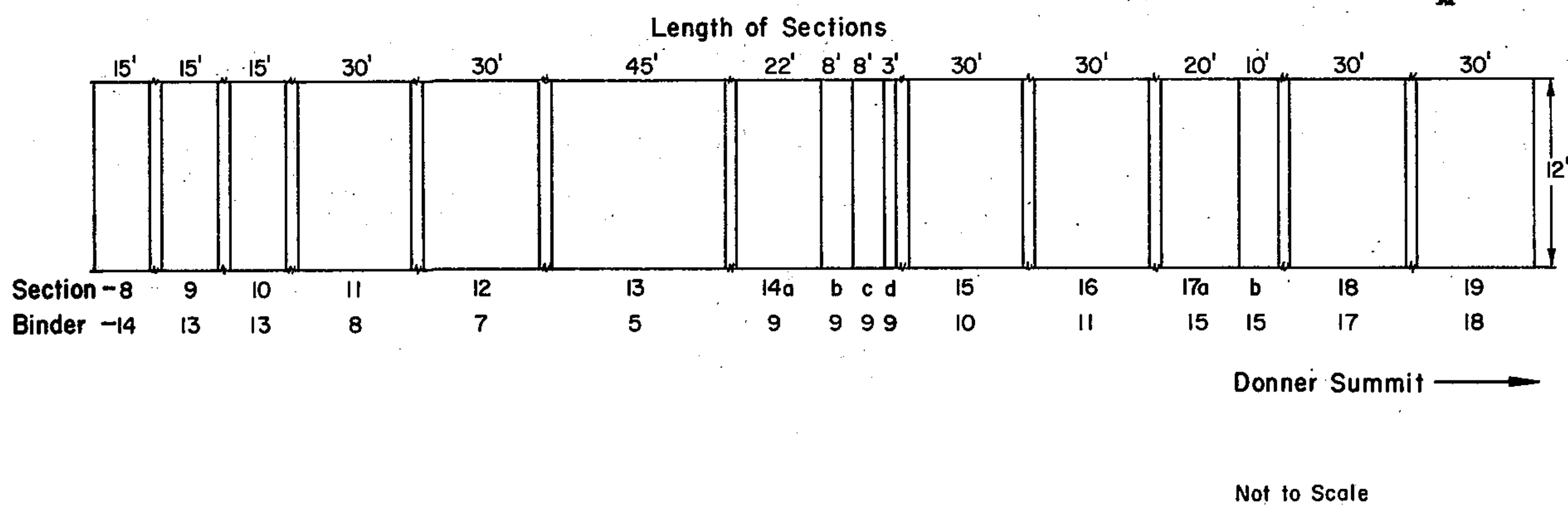


CHART 3

SACRAMENTO APPLICATION DETAILS

Section	Binder	How Applied	Date and Time	Filler	Approx. Binder or Overlay Thickness	Blistering
1	1	Broyhill	6-2-65 11:30	10-20 Gopher Sand	3#/yd^2 binder	Severe
2	2	Broyhill (Murphy)	6-3-65 14:00	"	3#/yd^2 binder	Moderate
3	3	Hand with Squeegee and Roller	6-2-65 11:30	"	1½#/yd^2 binder	Moderate
4	12	"	6-3-65 14:30	"	*1/4" Final Thickness	None
5	4	Hand	6-3-65 14:30	"	3#/yd^2 binder	None
6 a	6	Broyhill (Murphy)	6-2-65 13:35	"	3#/yd^2 binder	None
6 b	6	Trowel	6-2-65	Not Known	1/4" Final Thickness	Moderate
7 a	16	Trowel	6-2-65	Not Known	1/4" Final Thickness	Moderate
7 b	16	Broyhill (Murphy)	6-2-65 16:00	10-20 Gopher Sand	3#/yd^2 binder	None
7 c	16	"	6-2-65 16:00	20-40 Gopher Sand	3#/yd^2 binder	None
7 d	16	"	6-2-65 16:00	8-16 Bear River Sand	3#/yd^2 binder	None

KEY BINDER 1 - 11 Light colored epoxy
12 - 14 Polyester
15 - 18 Dark colored epoxy

*Applied in three layers of binder and aggregate rolled between layers.

CHART 4

KINGVALE APPLICATION DETAILS

Sec.	Binder	Date and Time	Filler	Approx. Binder or Overlay Thickness	Blistering	Remarks
8	14	5-31-66 12:30	10-20 Gopher	3#/yd^2	None	Preprimed .7#/yd^2 (50% styrene)
9	13	6-1-66 09:30	"	8#/yd^2	None	Placed in three layers
10	13	6-1-66 11:15	"		Prime Yes	Concrete primed with epoxy, placed in 3 layers
11	8	6-1-66 11:15	"	3#/yd^2	Some	
12	7	6-1-66 11:30	"	2.5#/yd^2	None	
13	5	6-1-66 10:00	"	3#/yd^2	Some	
14a	9	6-3-66 09:15	"	3#/yd^2 Total	Some	
14b	9	6-3-66 11:40	"	6#/yd^2 Total	Some	Placed in two layers after 1st layer partially set
14c	9	6-3-66 11:00	8-12 sub-angular sand	3#/yd^2	None	
14d	9	6-3-66 11:40	Walnut 8-20	3#/yd^2	None	
15	10	6-3-66 10:30	10-20 Gopher	3#/yd^2	None	
16	11	6-3-66 AM	"	3#/yd^2	None	
17a	15	6-2-66 AM	"	3#/yd^2	None	
17b	15	6-1-66 AM	"	6#/yd^2 Total	None	Lightly blasted before second layer.
18	17	6-1-66 AM	"	3#/yd^2	Mod.	
19	18	6-2-66 PM	"	3#/yd^2	None	

Binder applied by hand broom, roller or screed.

TESTS 1 THROUGH 11

PHYSICAL PROPERTIES OF RESINOUS MATERIALS

Test		Binder	1	2	3	5* 4	7* 6	8	9	10	11	12	13	14	15* 16	18
1	Brookfield Viscosity poises	A	8.5	71	250	14	51	17	8	32	56	8	10		16.3	97
		B	14	20	6160	10	0.80	79	15	4.5	7.5				4	32
		Mixed		28												72
2	Cure 7 days @ 25°C	Tensile, PSI	639	453	3655	575	1040	665	524	708	514	3963	1720	901	462	838
		% Elongation	104	53	10	58	38	44	84	29	63	23	63	85	53	36
3	Cure 7 days @ 25°C + 14 days @ 70°C	Tensile, PSI	1155	465	681	840	725					5310	1973		1724	826
		% Elongation	62	36	50	48	72					28	44		20	4
4	Cure 7 days @ 25° C + 100 hrs. in Fadometer	Tensile, PSI	685	254	898	488	1096					5070	2101		735	932
		% Elongation	91	43	38	44	33					24	51		36	26
5	% Reflectance after 100 hrs. in Fadometer	Original	34	47	16	44	67	19	47	32	54	6	9	11		
		Final	10	26	8	37	44	18	47	28	39	6	9	11		
		% Change	71	45	50	16	34	5.3	0.0	12.5	25.9	0.0	0.0	0.0		
6	% Water Absorption ASTM D570 59T		.32	.17	2.1	.61	.20	.63	.92	.58	.71	.75	1.3	1.2	.41	.40
7	Tensile Adhesion Calif. 420A	PSI	220 **	318 **	272 **	263 **	261 **					174 ***	143 ***		274 **	260 **
8	Freeze-Thaw		Pass	Pass	Fail	Pass	Pass		Pass			Pass	Pass		Pass	Pass
9	Volatile Distillation Mls ASTM D1078	A	12.1	0.0		2.0	0.40		7.4						0.0	6.5
		B	2.0	0.2		1.0	0.00								0.4	0.4
10	Gel Time, min. 60 gms		15	23	42	20	50		15	48	22	100	32		43	110
11	Compressive Strength,	PSI	1586	1344	10231	1277	2188		1900			5105	3240		1596	4341

*Similar Product - not analysed. ** Concrete fail *** Bond Fail

FIGURE 1

TEST 12 SHORE D HARDNESS

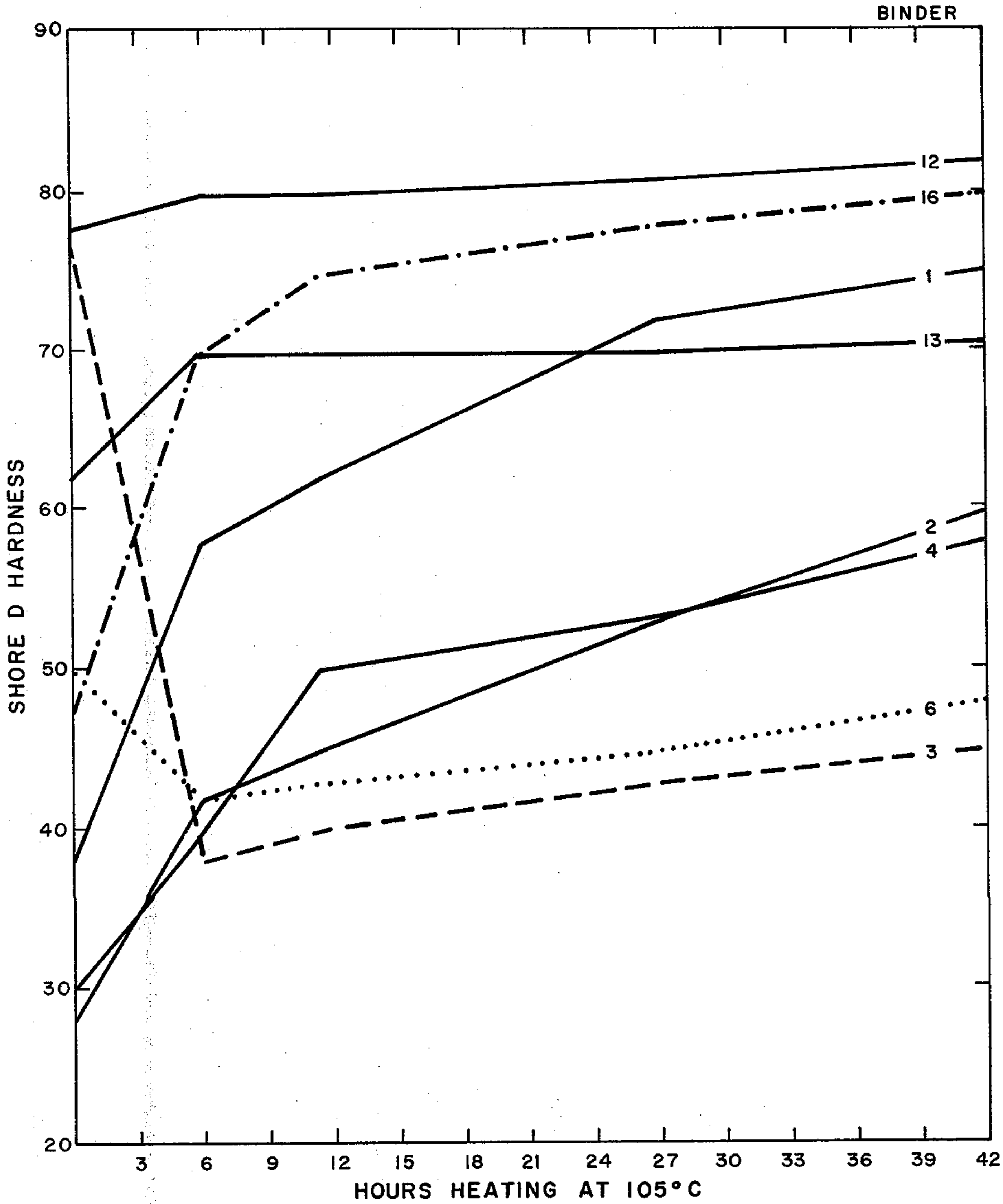


FIGURE 2

TEST 13 WEIGHT LOSS DURING HEAT AGING
AT 70° C FOR 42 HRS.

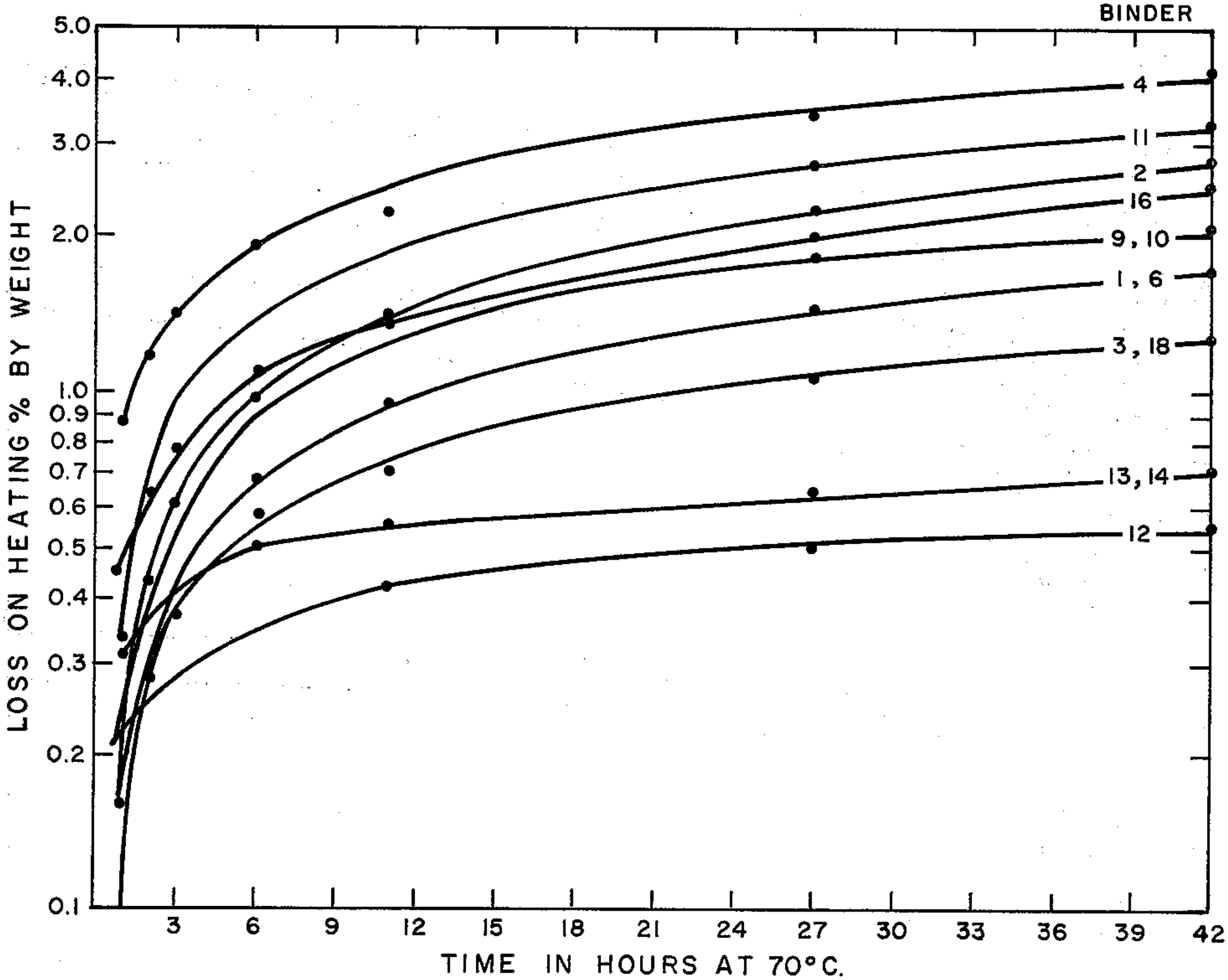


FIGURE 3

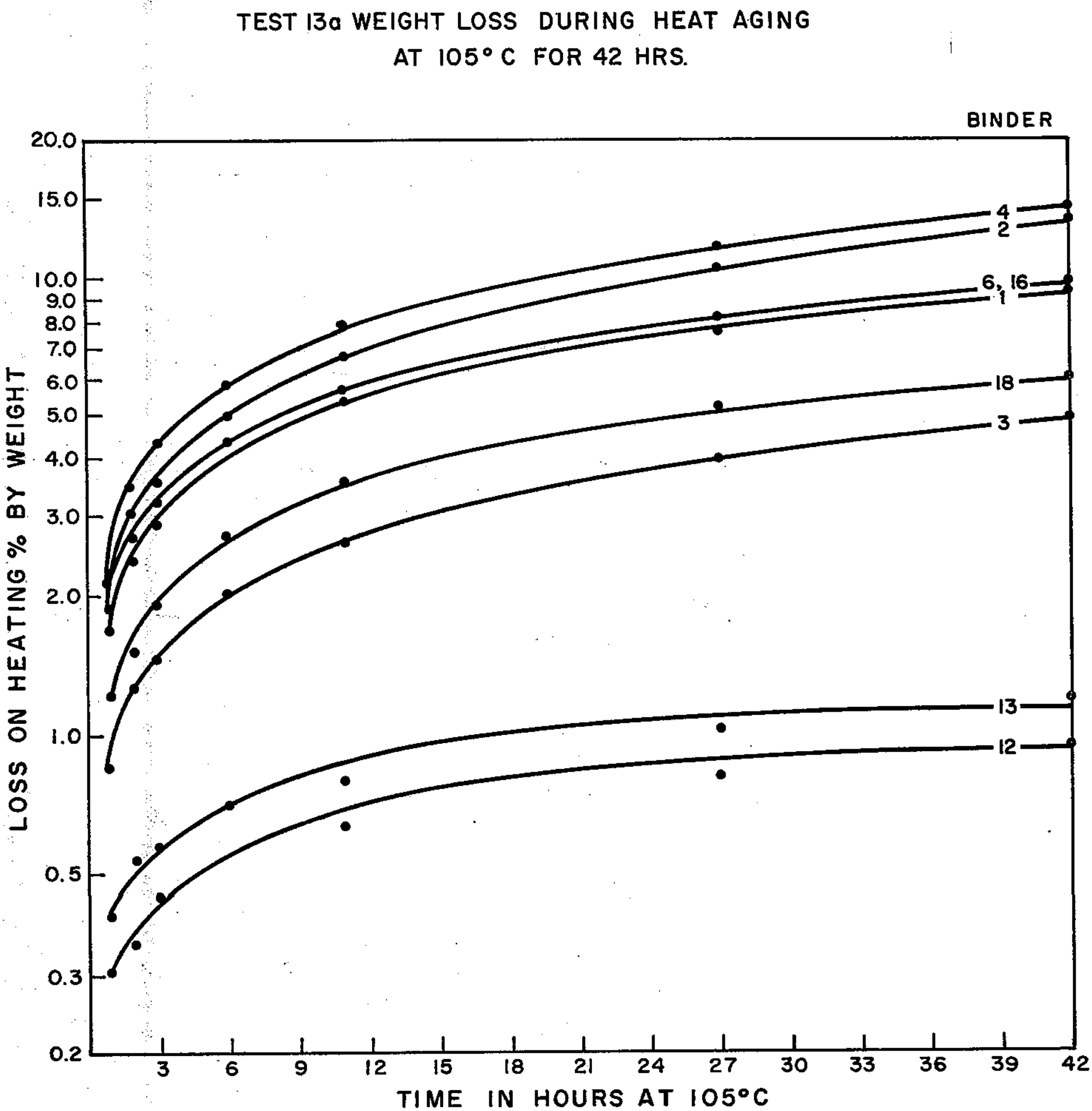
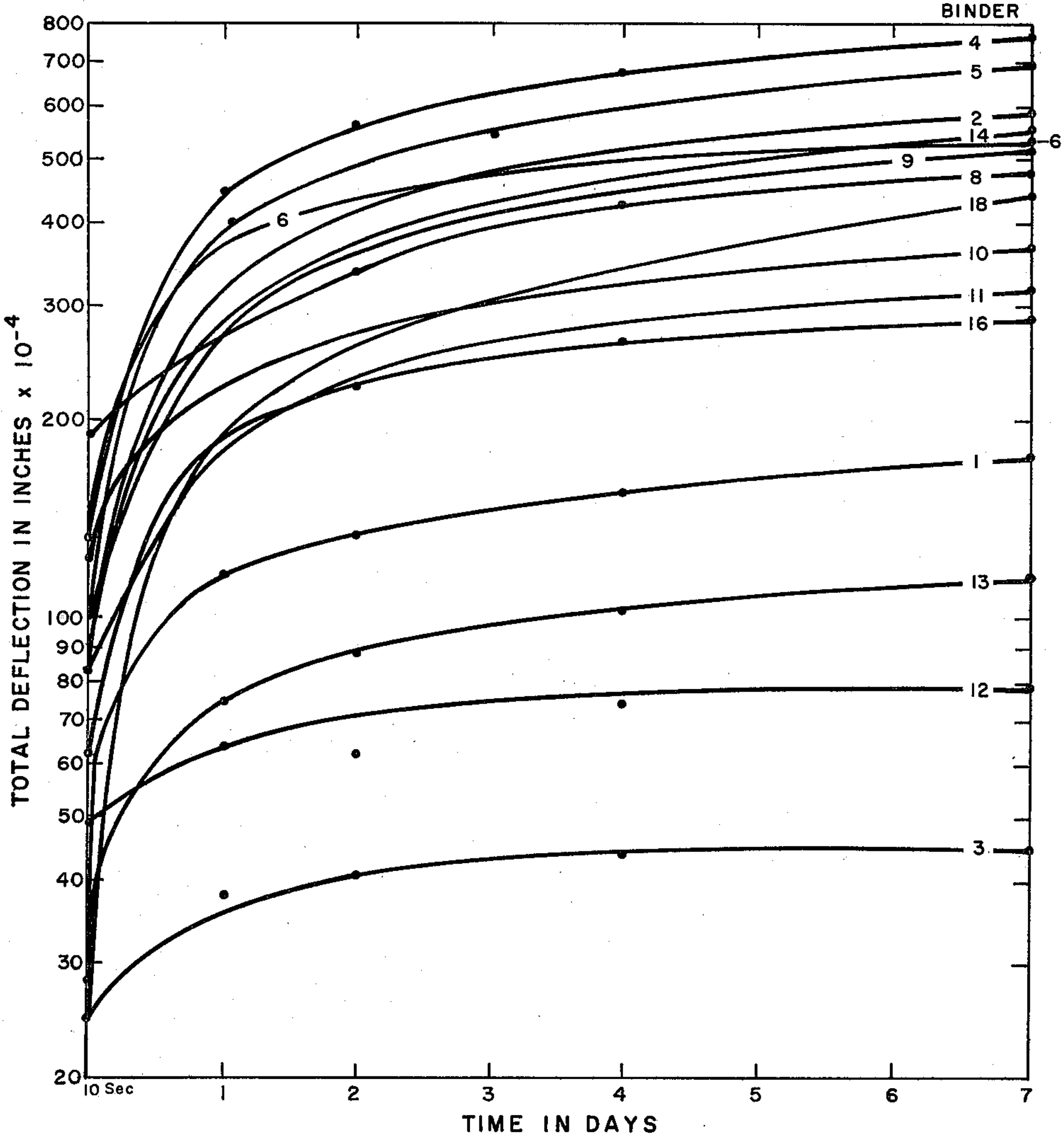

TEST 13a WEIGHT LOSS DURING HEAT AGING
AT 105° C FOR 42 HRS.
BINDER
LOSS ON HEATING % BY WEIGHT
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.5
0.3
0.2
4
2
6, 16
1
18
3
13
12
3
6
9
12
15
18
21
24
27
30
33
36
39
42
TIME IN HOURS AT 105°C

FIGURE 4

TEST 14 LOW TEMPERATURE CREEP



TEST 15

ABRASION TESTS ON AGGREGATES USING A COMMON BINDER

	Wt. Loss (gms) 1st Cycle	2nd Cycle
10-20 mesh Gopher sand (rounded)	8	4
8-12 mesh Bear River sand (angular or sub-angular)	10	5
Silicon Carbide No. 16 mesh	7	3
Garnet 12 mesh	12	6

Grading on 10-20 mesh Gopher sand used:

Sieve Size	% Passing
#10	100
#16	93
#20	19
#25	4
#30	2

TEST 16

FLASH POINTS OF XYLENE ADDED TO AN EPOXY CONTAINING 10-12% BUTYL GLYCIDYL ETHER

Tests performed according to ASTM D93 in Pensky Martens apparatus:

Epoxy with 10-12% BGE	167°F
5% by vol. Xylene	128°F
+3% by vol. Xylene	148°F
+2% by vol. Xylene	155°F
+1% by vol. Xylene	165°F

TEST 17

FIELD TENSILE TEST - SACRAMENTO

Section	Binder No.	PSI After 25 Months Service	PSI After 39 Months Service
1	1	200	605
2	2	320	380
3	3	495	525
4	12	125	255
5	4	185	605
6a Sec. 1	6	85	285
6a Sec. 2	6	220	605
6a Sec. 3	6	230	605
6b	6	70	510
7a	16	230	414
7b Sec. 1	16	115	478
7b Sec. 2	16	40	-
7b Sec. 3	16	70	382
7c	16	-	-
7d	16	-	350

TEST 17

FIELD TENSILE TEST - KINGVALE

Section	Binder	1 PSI After 3 Months Service	2 PSI After 12 Months Service	3 PSI After 28 Months Service
8	14	85	Overlay gone	Overlay gone
9	13	90	Overlay gone	Overlay gone
10*	13	300	70	195
11	8	270	80	75
12	7	190	150	150
13	5	300	95	140
14a	9	200	15	150
14b	9	245	50	180
14c	9	240	65	Overlay gone
15	10	190	80	Overlay gone
16	11	135	40	165
17a	15	225	70	290
17b	15	235	40	280
18	17	340	180	135
19	18	225	80	Overlay gone

*Epoxy prime

1. Higher values of 250 psi and above pulled considerable concrete.

2. No concrete was pulled in these late spring tests; lower values (all failures being in adhesion or cohesion) are attributed to moisture action during a severe winter and late spring.

3. Test values taken during early fall 16 months after 2 above, show that the adhesive and cohesive strength of adhesive improved greatly. Some concrete was pulled with highest values.

TEST 18

SKID RESISTANCE - SACRAMENTO

Test After Placement	1 Week		10 Months		22 Months		32 Months		42 Months	
	OWT	BWT	OWT	BWT	OWT	BWT	OWT	BWT	OWT	BWT
Control (Adjacent PCC)	.21	.34	.21	.33	.18	.32	.21	.33	.21	.35
Range of 7 Overlays using 10-20 Gopher Sand Min.	.36	.38	.31	.34	.28	.32	.26	.29	.26	.30
Max.	.39	.40	.34	.35	.31	.39	.32	.37	.31	.37
Average of above	.37	.39	.32	.34	.29	.34	.30	.32	.27	.33
Overlay 20-40 Gopher Sand	.38	.40	.28	.33	.21	.32	.23	.28	.28	
Overlay Bear River Sand	.41	.41	.37	.42	.35	.42	.33	.42	.37	
Trowel Sec. 6b	.29	.29	.20	.26	.24	.25	.30	.29	.35	
Trowel Sec. 7b	.18	.21	.13	.20	.12	.14	.14	.15	.16	

The general tentative minimum requirement for skid resistance is .25.

OWT = Outside Wheel Track

BWT = Between Wheel Track

TEST 18

SKID RESISTANCE - KINGVALE AREA

1. Values from overlays placed previous to this project. Age 1-1/2 years.

	OWT	BWT
Control (Adjacent PCC)	.25	.24
Overlays	.27	.26

2. Values of overlays placed fall of 1968 (not part of this project) age 6 months, winter conditions.

Control (Adjacent PCC)	.15 .16	.18 .23
Overlay No. 1	.19	.20
Overlay No. 2	.19	.21
Overlay No. 3	.17	.22

3. Values of section 10, polyester, placed under this project.

Control (Adjacent PCC)	.20	.24
Overlay No. 10	.16	.19

See preceeding page for comments on skid requirements.

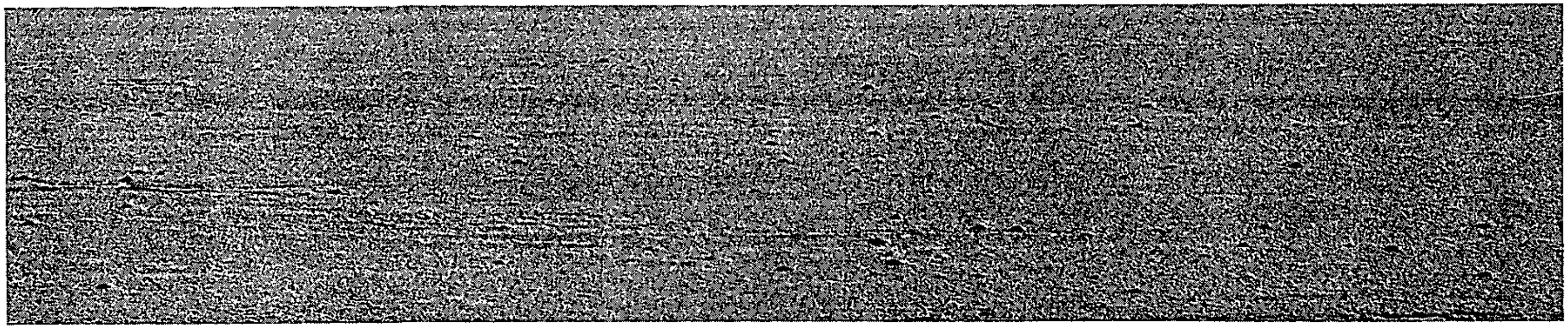
RATE OF WEAR OF OVERLAYS AT KINGVALE

(% OF OVERLAY INTACT ON ROADWAY)

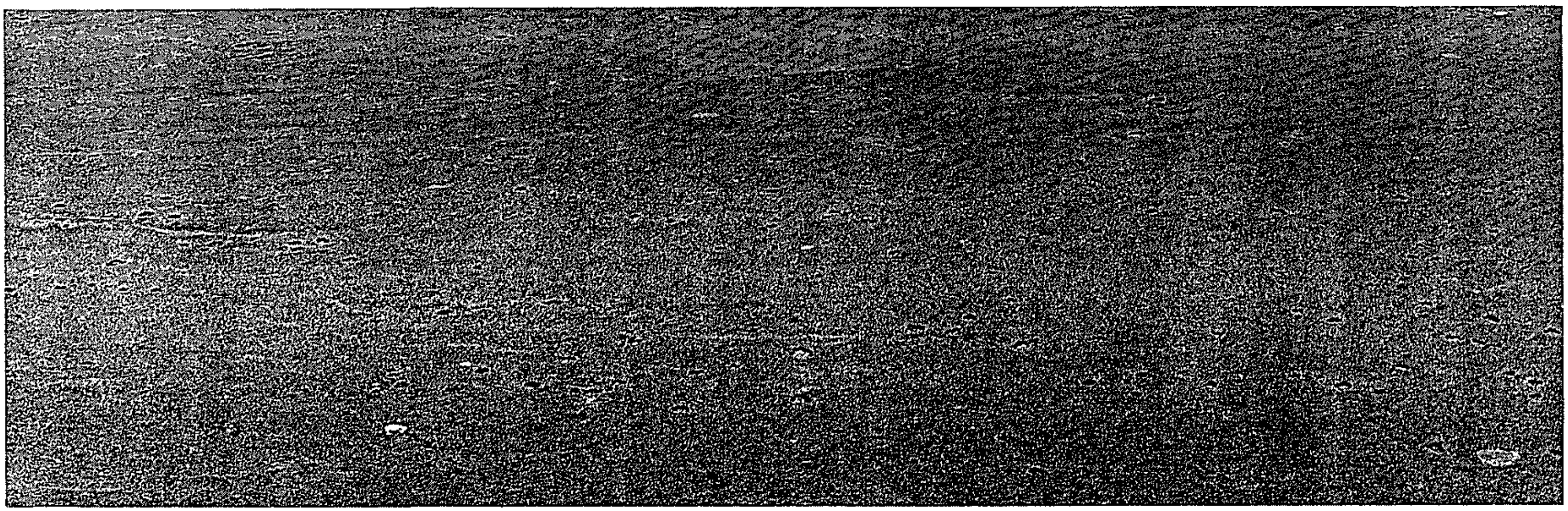
Section	12 Months	20 Months	28 Months
8	2	2	0
9	5	2	0
10	99*	98*	98*
11	75	60	45
12	75	50	20
13	90	70	50
14a	85	65	50
14b	100	98	90
14c	95	65	45
14d	0	0	0
15	25	10	0
16	60	25	2
17a	85	60	40
17b	100	95	90
18	50	40	5
19	30	5	2

* Primer blister broken

FIGURE 5

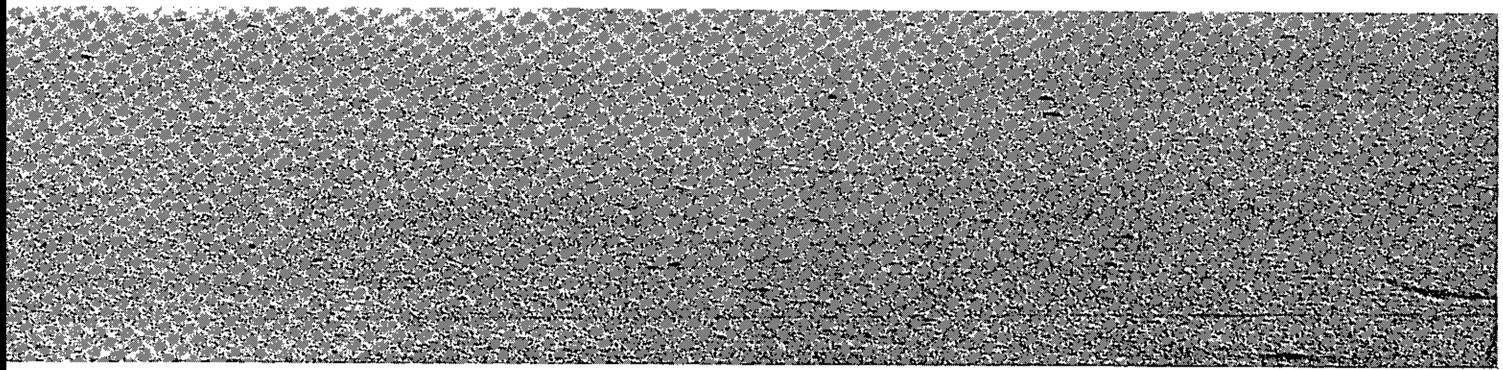


Binder blistering - Section 1 - Sacramento Installation. State Specification 1R413a (contaminated with solvent). Photographed facing sun to best show blisters.

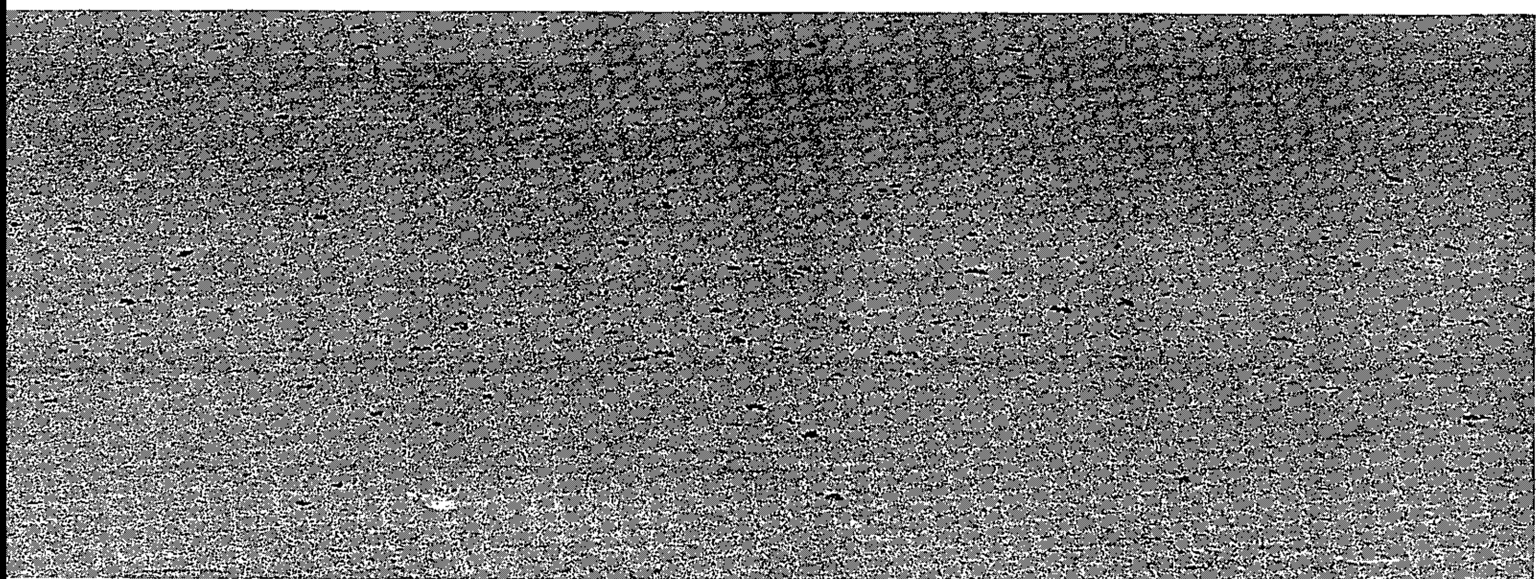


Same section as above after 3 years service. Blisters broken and concrete exposed.

FIGURE 6



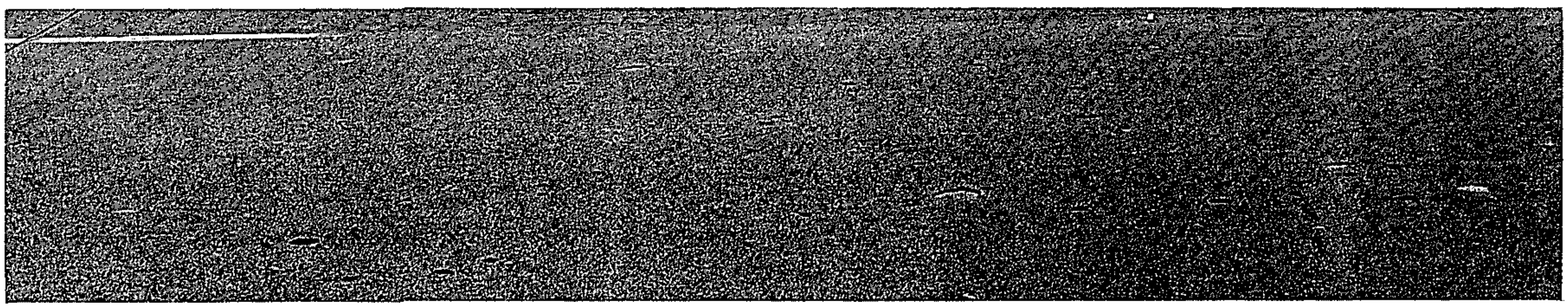
2 - Adhesive Engineering 1064-3 - Section 2 - Sacramento Installation, seal
Photographed after installation, facing sun to best show blistering.



section as above after 3 years service. Blisters broken and concrete exposed.

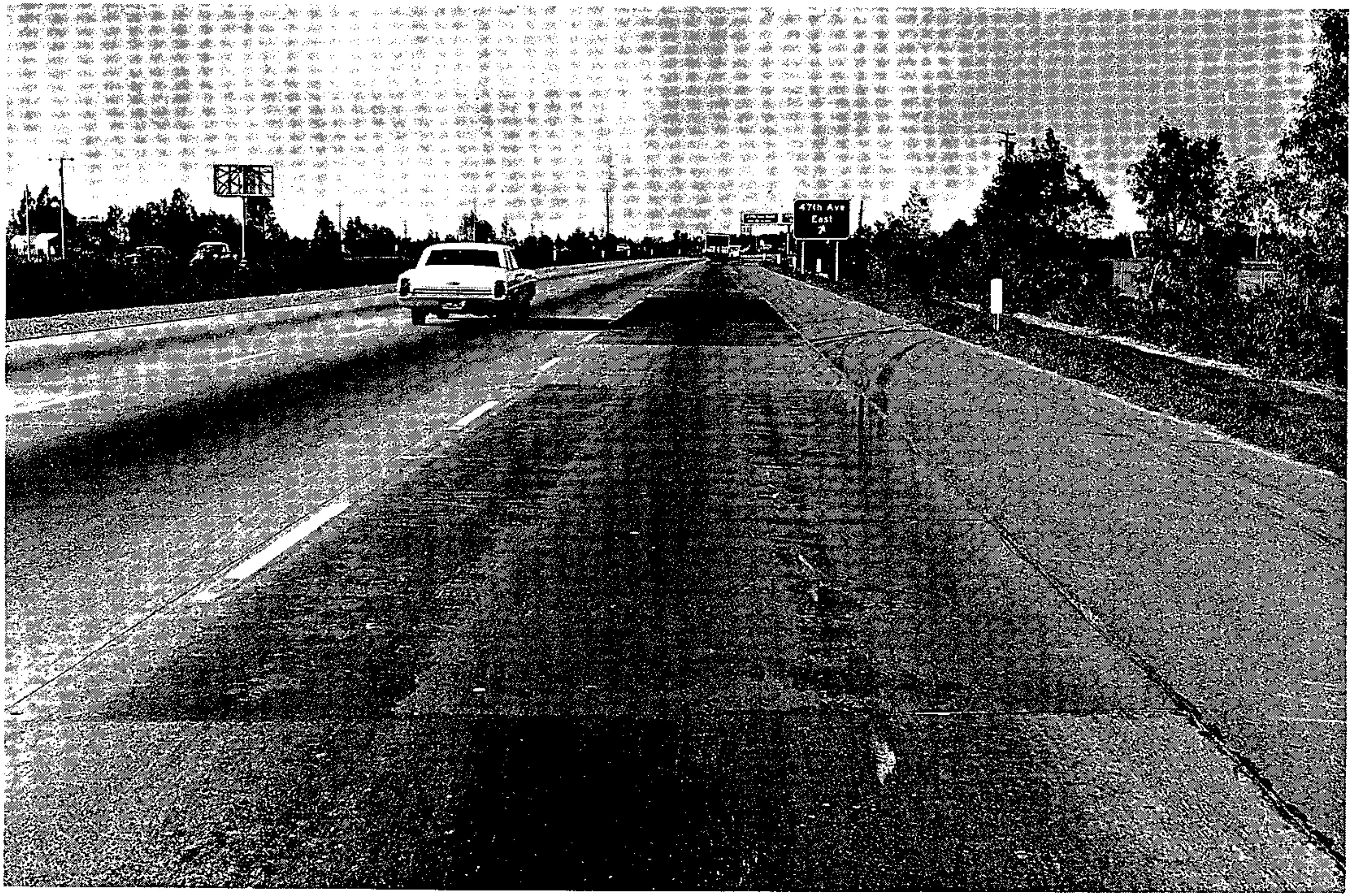
FIGURE 7

Binder 6 - Guardkote 250 - Section 6b - Sacramento Installation, trowel section. Photographed facing sun to best show blistering.



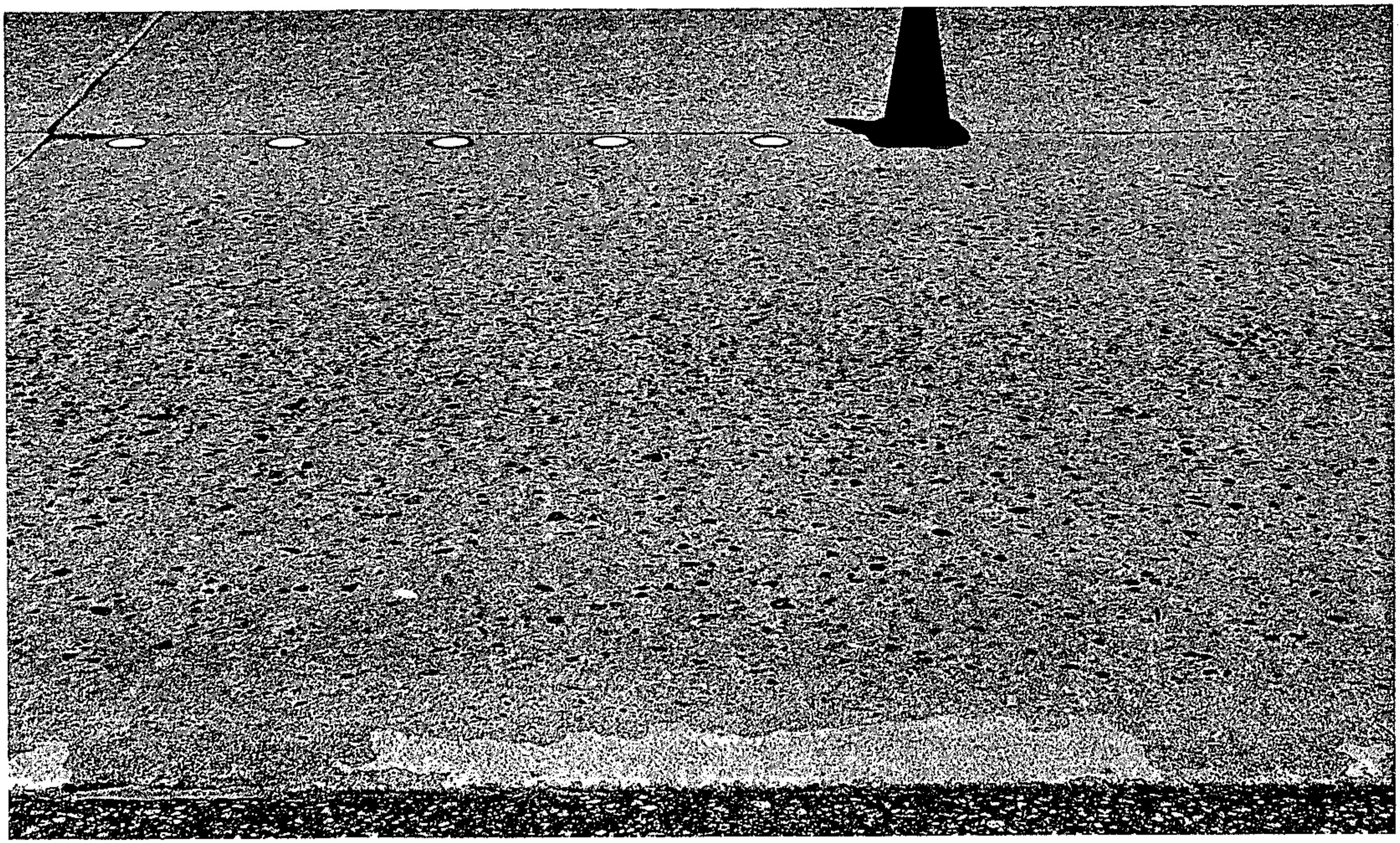
Same section as above after 3 years service. Many, but not all, of the original blisters broken; some spalling extending beyond original blister.

FIGURE 8



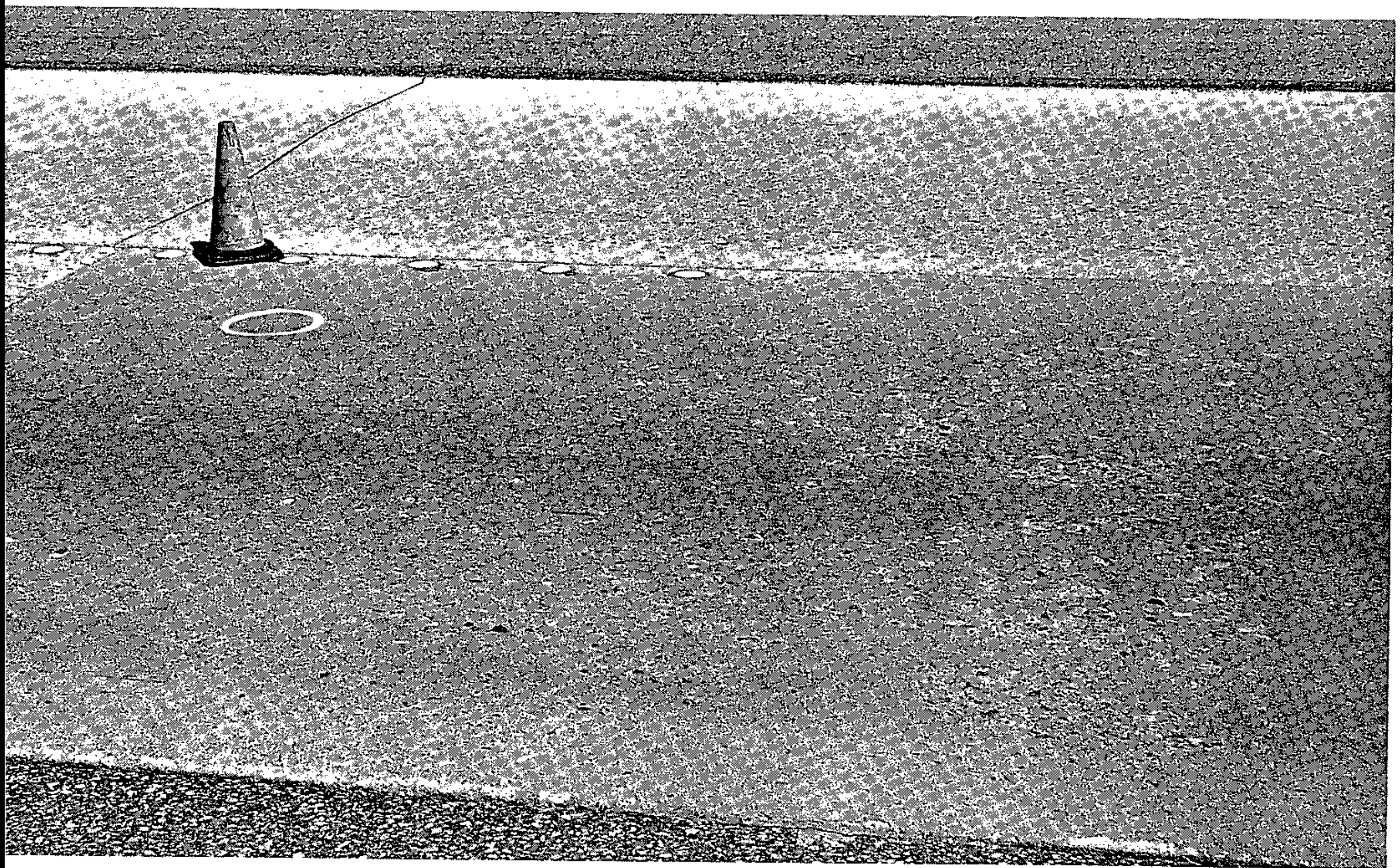
Binder 6 - Guardkote 250 - Section 6a - Sacramento Installation, seal coat. Overlay completely worn away in wheel tracks after 3-1/2 years of service.

FIGURE 9



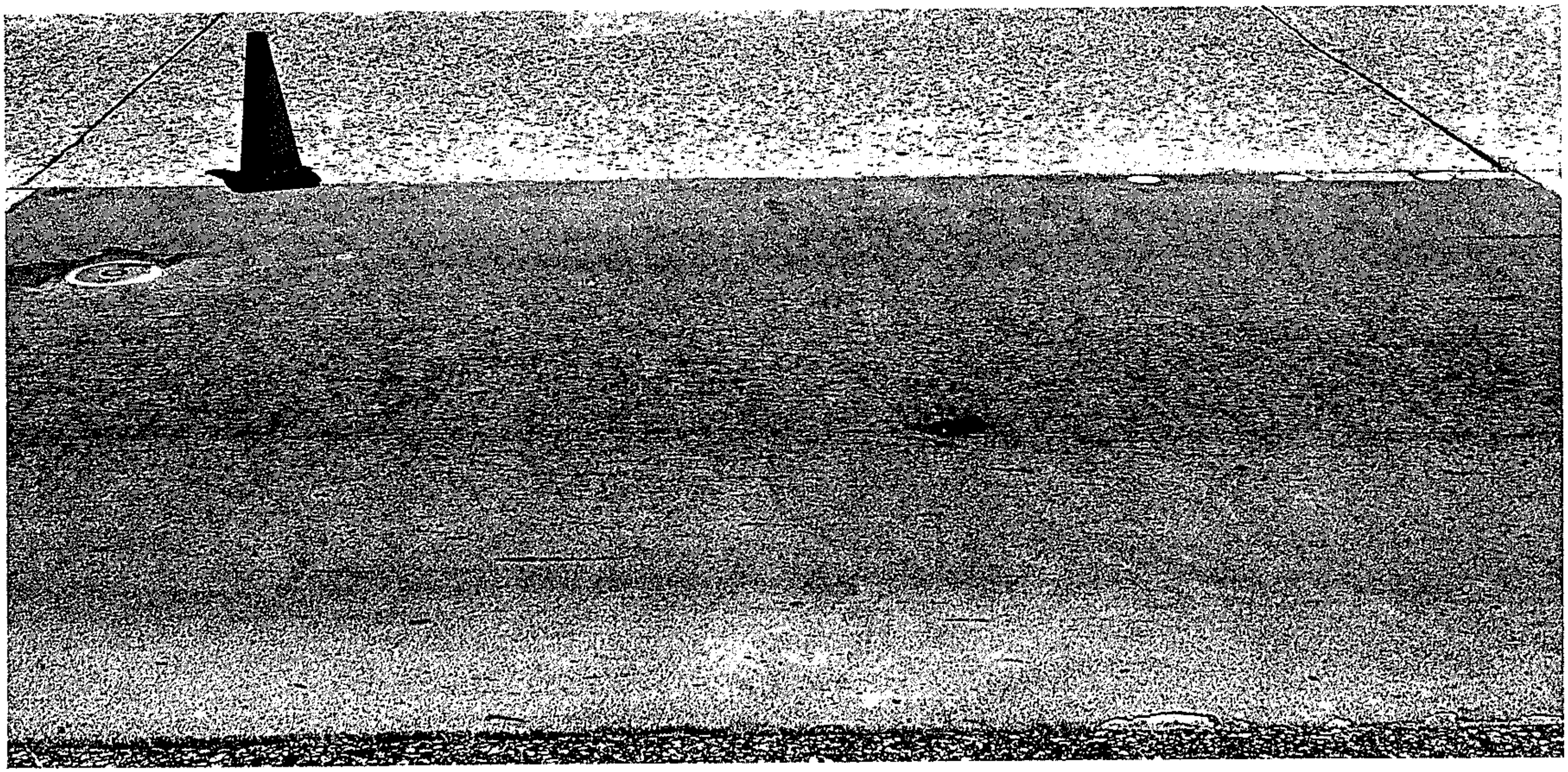
Binder 14 - Chevron Polyester - Section 8 - Kingvale Installation, seal coat. Overlay completely gone after one year due to lack of bond of polyester to concrete.

FIGURE 10



nder 5 - H. B. Fuller 7121 - Section 13 - Kingvale Installation, seal coat after e year. Typical wear of the better single applications of epoxy seal coat. Note at wear is not appreciably more severe in the wheel tracks.

FIGURE 11

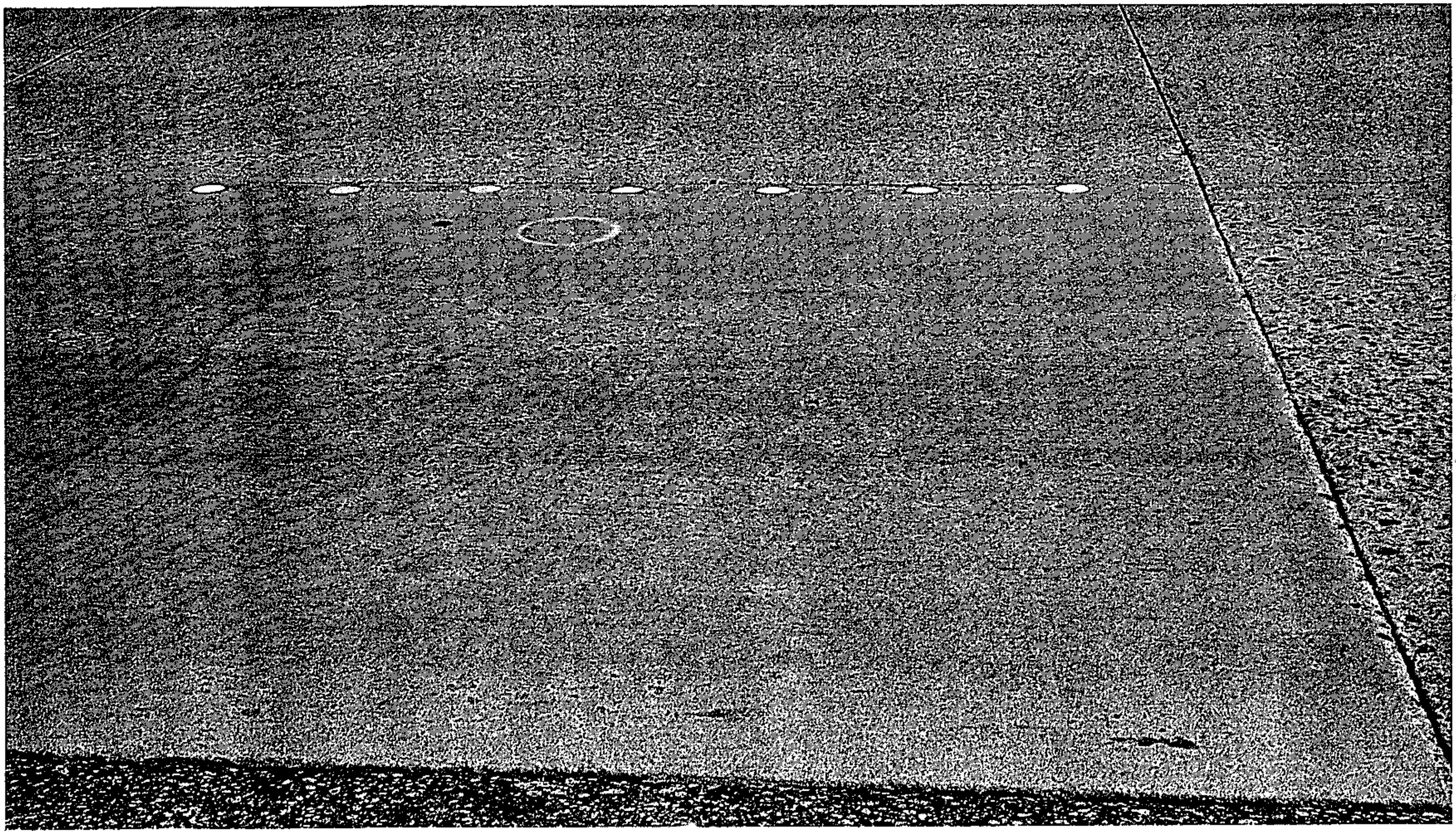


Binder 13 - Reichhold Polylite - Section 10 - Kingvale Installation, 3 layer polyester seal coat over epoxy primer. Condition good at one year.

FIGURE 12

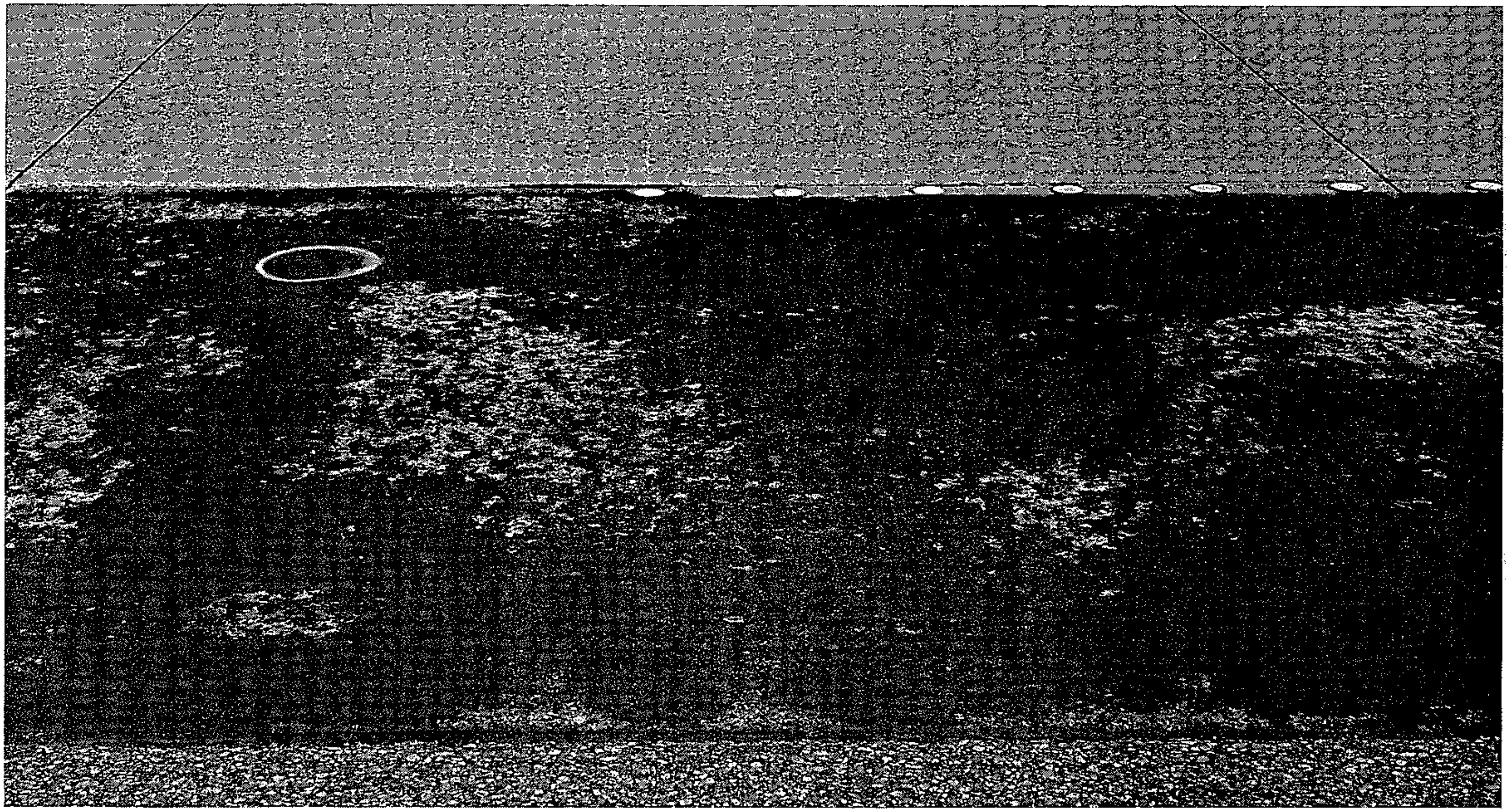
· Kingvale Installation - Section 14a - State Specification 66-F-46 (now
). Single application seal coat. Wear after one year approximately same as
3. Wear at left of section is due to snowplow blade catching on leading edge
7.

FIGURE 13



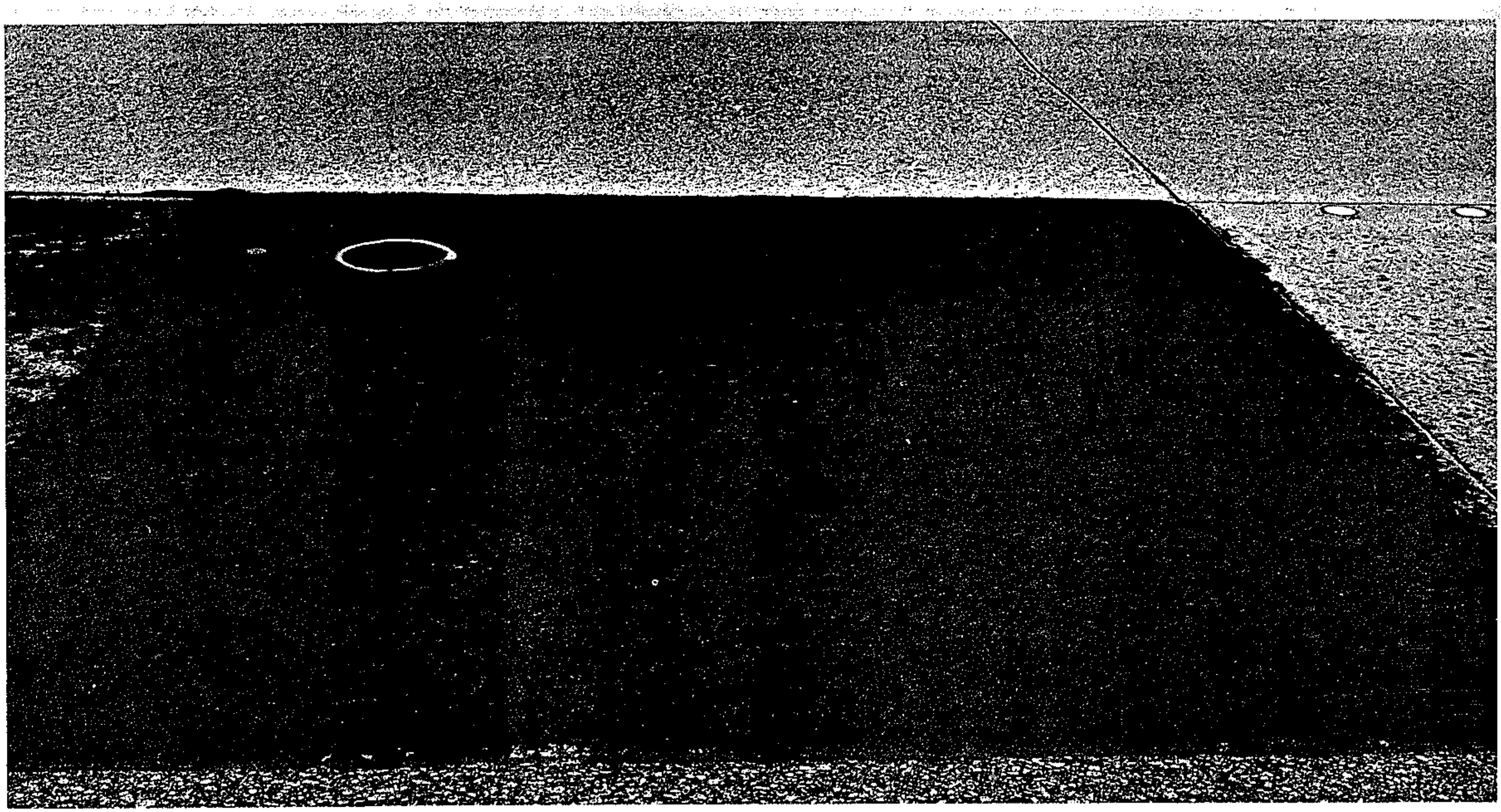
Binder 9 - Section 14b - Kingvale Installation. State Specification 66-F-46 (now 681-80-46). Double application seal coat. Condition good at one year.

FIGURE 14



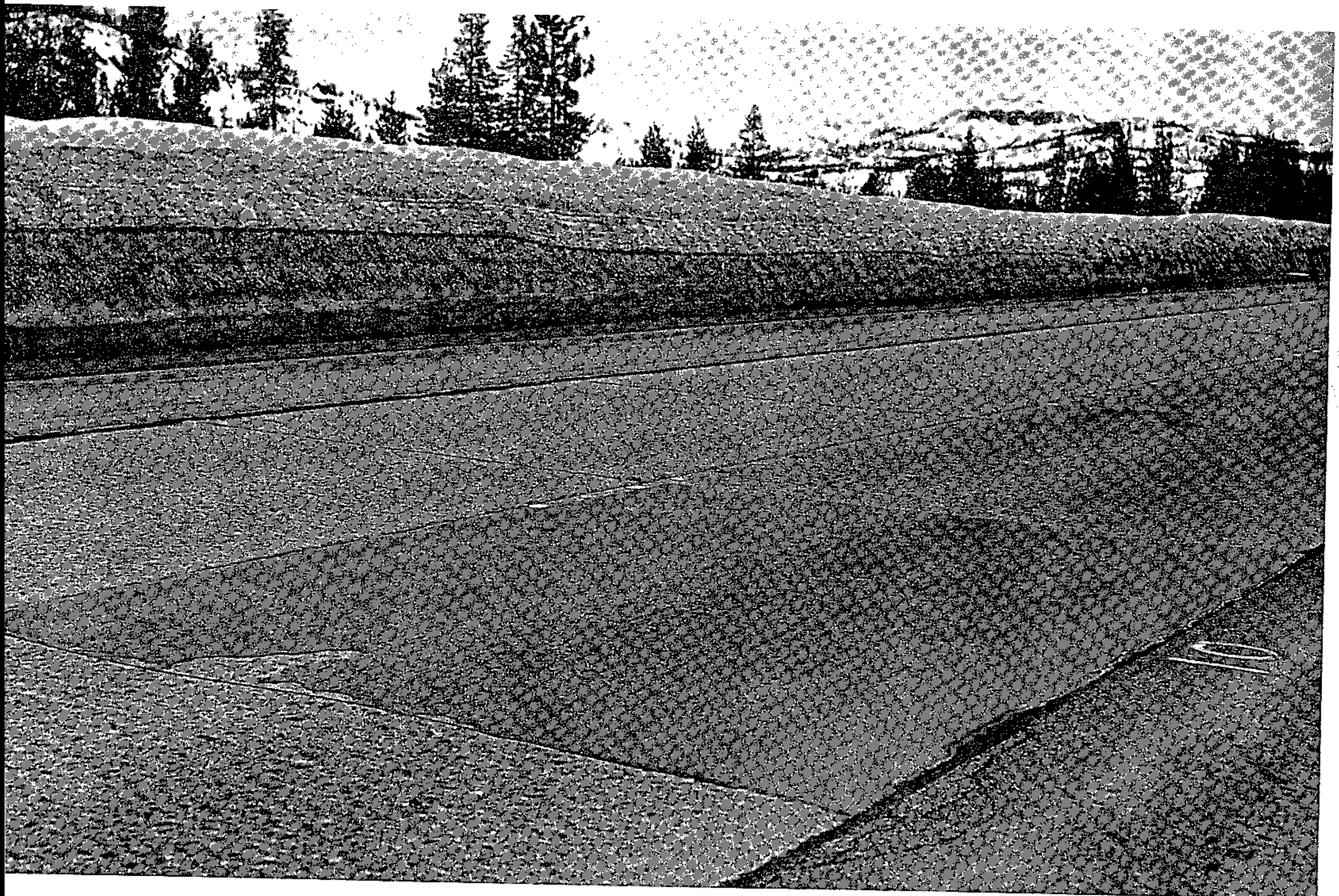
Binder 15 - Guardkote 140 - Section 17a - Kingvale Installation; single application seal coat. Wear after one year somewhat greater than Section 13 and 14a.

FIGURE 15



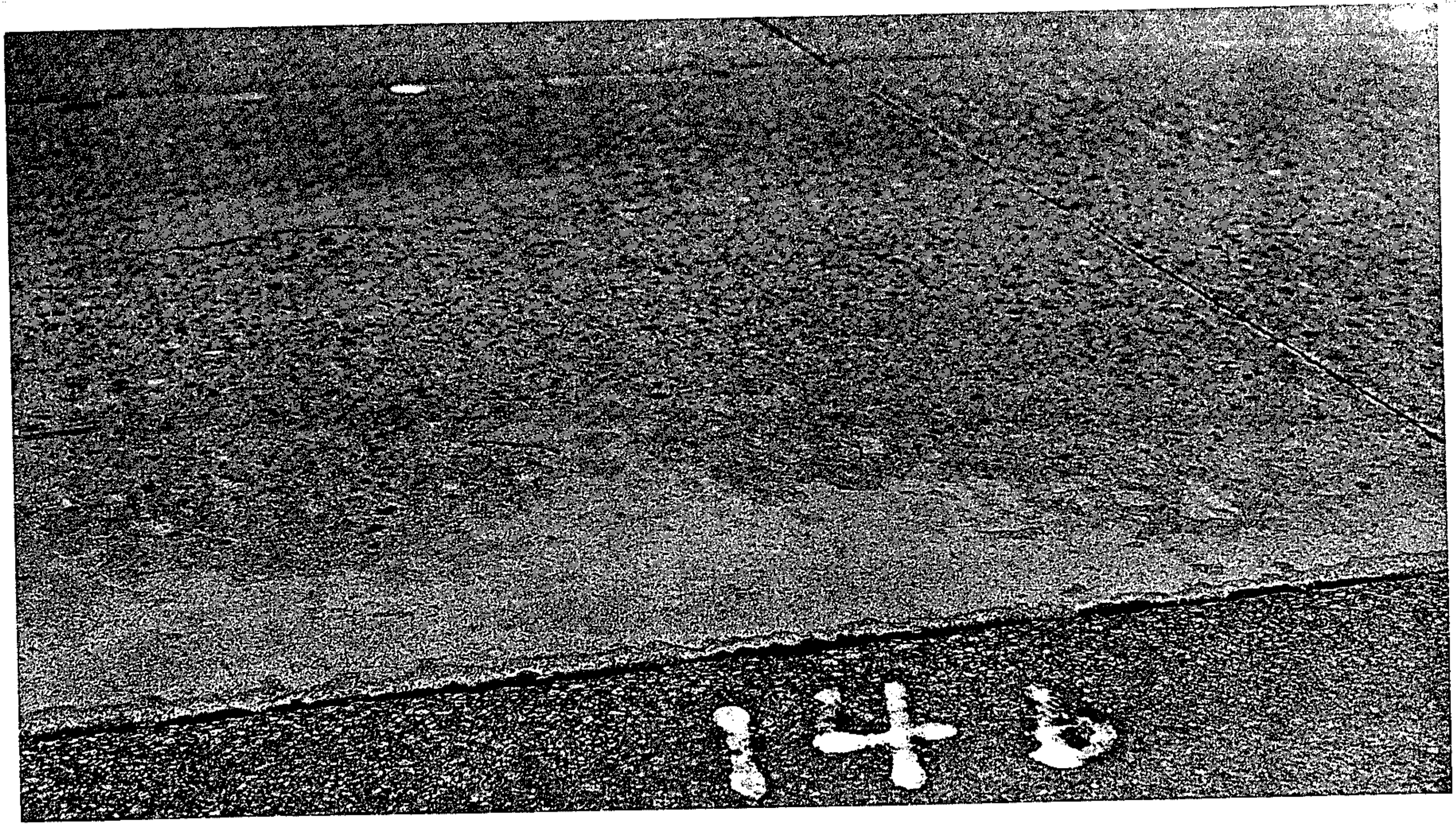
Binder 15 - Guardkote - Section 17b - Kingvale Installation; double application seal coat. Good condition after one year.

FIGURE 16



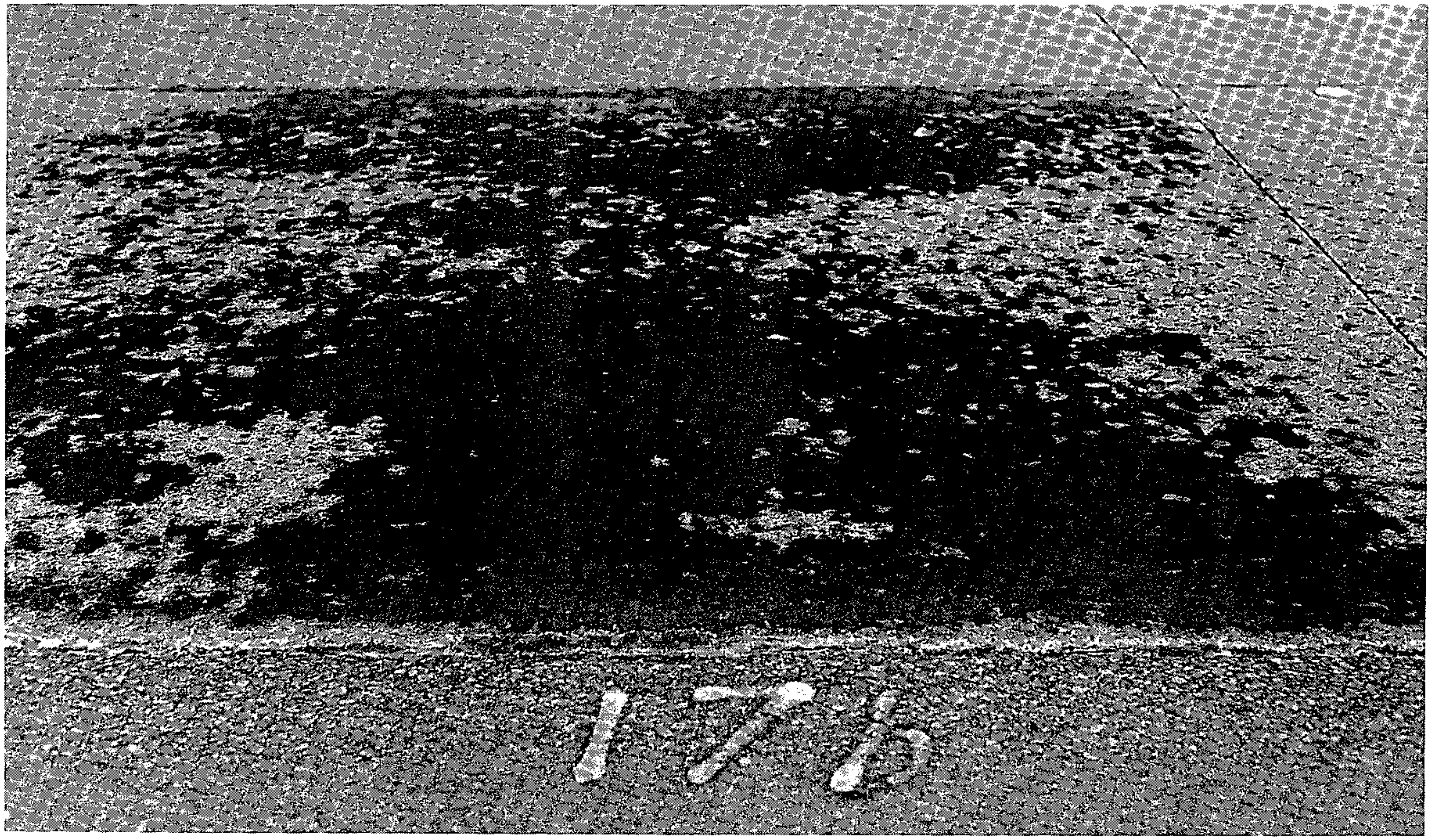
der 13 - Reichhold Polylite - Section 10 - Kingvale Installation. Three layer yester seal coat over epoxy primer. Condition after nearly three years of service. ll pits were caused by blisters in epoxy primer coat. Delamination at near edge is sed by snowplow blade catching on overlay.

FIGURE 17



Binder 9 - Section 14b - Kingvale Installation - State Specification 66-F-46 (now 681-80-46) double application seal coat. Condition after nearly three years service.

FIGURE 18



Binder 15 - Guardkote 140 - Section 17b - Kingvale Installation. Condition after nearly three years service. Failure appeared to be mostly due to abrasion from the top surface despite low tensile adhesion values under damp conditions. More failure in adhesion was experienced with the other modified epoxy formulations.

FIGURE 19

Binder 9 - Section 14b - Kingvale Installation. Condition at nearly three years service (photographed in March). This demonstrates the low adhesion during winter and spring months. This was experienced with most other modified epoxy formulations and was verified by tensile adhesion tests. (See Appendix Page 12).

TEST METHOD

1. Viscosity

Stir each component thoroughly with a spatula and adjust temperature to 25°C. Measure viscosity with a Model RVT Brookfield viscometer proper spindle and rpm.

2. Tensile Strength and Percent Elongation After 7 Days Cure at 25°C.

The mixed epoxy is cast on a leveling table. The table consists of milled and polished steel, 15" x 12" x 1/2" with leveling screws on each corner. A steel gasket, also milled and polished, 1/2" wide, 1/4" thick is fitted around the periphery of the steel plate and held in place by means of set screws, drilled and tapped through the gasket into the surface of the steel plate. Eight set screws are used, set at equi-distant spaces. The gasket sits on the Mylar sheet and keeps the Mylar from wrinkling. After the Mylar sheet is placed and gasket positioned and screwed into base, the table is leveled and mixed epoxy poured on to the Mylar to a depth of 0.125 inches, depth being controlled by measuring with a thickness gauge. After proper depth is obtained the surface of the epoxy is then heated with an electric heat blower to flash off entrapped air.

Cure the epoxy sheet for 7 days at 25°C. Strip the epoxy sheet from the Mylar film. Cut specimens from sheet according to ASTM D 638-61T, except that the narrow width of the cut is 0.50 inches. Test specimens at the rate of 0.2 inch per minute.

3. Tensile and Elongation After 7 Days Cure at 25°C plus 14 Days at 70°C.

Cast and cure 1/8" epoxy sheet for 7 days at 25°C as described previously. Cut specimens and place in 70°C forced air oven for 14 days, allow to cool and test as before.

4. Tensile and Elongation After 7 Days at 25°C plus 100 Hours in Atlas Fadometer.

Cut specimens from cured sheet after normal cure schedule and expose to 100 hours ultra violet radiation in the Atlas Fadometer. Measure tensile and elongation as before.

5. Reflectance, Original and After 100 Hours in Atlas Fadometer.

Cut specimen from 1/8" normal cured epoxy sheet and expose to 100 hours ultra voilet radiation in the Atlas Fadometer. Measure reflectance in a Photovolt meter before and after exposure using a tri-green filter. Percent change of reflectance between before and after readings is a measure of the color stability of the epoxy.

6. Water Absorption

Cut 3" x 1" strips, using a die, from 1/8" epoxy sheet cured as in (3). Weigh strips on an analytical balance to nearest milligram and immerse in distilled water for 7 days at 25°C. Remove the strips, wipe dry with tissue and immediately weigh. Gain in weight is calculated as percent water absorption.

7. Tensile Adhesion

Cast a 1/8" thick mortar on the surface of a 12" x 12" x 3" sandblasted concrete block and cure for 1 week at 25°C. Mortar is made using a sand to binder ratio of 3:1 by volume. Sand used is a blend of equal parts by volume of Ottawa C190 and Ottawa C109. After cure is complete measure adhesion according to California Test Method 420A.

8. Freeze-Thaw

Cast a 1/2" thick mortar on the surface of a 12" x 12" x 3" sandblasted concrete block and cure for 1 week at 25°C. Mortar is made using a sand to binder ratio of 2.5:1 by volume. Sand used is a blend of equal parts by volume of Ottawa C190 and Ottawa C109. After cure is complete, subject blocks to 5 cycles of freezing and thawing from -6°F to 77°F. Evidence of cracks in concrete constitutes failure.

9. Volatile Distillation

Do according to ASTM D1078-58 on each component and report as mls of distillate in 100 mls of sample.

10. Gel Time

Do according to Test Method No. Calif. 427.

11. Compressive Strength

Cast cylinders 2" diameter and 4" in height from a mortar consisting of a sand to binder ratio of 4:1 by volume. Sand used is a blend of equal parts by volume of Ottawa C190 and Ottawa C109.

Test Methods from State of California, Department of Public Works, Division of Highways, Materials Manual, Testing and Control Procedures.

Laboratory Tests:

Test 10-Test Method No. Calif. 427

Test 14-Test Method No. Calif. 419

Field Tests:

Test 17-Test Method No. Calif. 420 Part I
Test 18-Test Method No. Calif. 342

State of California
Department of Public Works
Division of Highways

SPECIFICATION

March, 1965

EXPERIMENTAL AROMATIC PETROLEUM OIL MODIFIED EPOXY RESIN BINDER

FORMULA 1R413A

Classification:

This epoxy resin adhesive is not designed for use in the bonding of fresh portland cement concrete to old portland cement concrete. Epoxy binder formula 1R413A is intended to be used with selected aggregates to form a quick setting epoxy mortar or concrete for use in the repair of pot holes or spalled areas on concrete structures or as a binder for thin extensive surface overlays on portland cement concrete highway surfaces and bridge decks. This binder was designed to have sufficient creep or stress relief at sub-zero temperatures to provide an epoxy mortar or concrete which would not rupture the adjacent portland cement concrete in tension because of the differences in the thermal coefficients of expansion of the epoxy mortar and portland cement concrete.

Composition:

Component A	Lbs./100 Gals.
Epoxy Resin, Shell 815, Ciba 506 or equivalent	869.5
Mobilsol 66, Mobil Oil Co. or equal	40.9
Titanium Dioxide RA-NC, Titanium Pig. Corp. or equal	37.4
Talc, Sierra, N. S. Silver or equal	43.5
Furnace Black - Witco F-1 or equal	.30
Cab-O-Sil M-5 or equal	2.6

Component B	
Reichhold Epotuf Hardener Code 37-610 or equal	433.4
Mobilsol 66, Mobil Oil or equal	392.7
Titanium Dioxide RA-NC, Titanium Pig. Corp. or equal	37.3
Talc, Sierra, N. S. Silver or equal	43.3
Cab-O-Sil M-5 or equal	5.2

All pigments must be properly dispersed so that there is no evidence of unwetted particles or of hard settling. Any settling must be readily dispersed with a paddle.

Properties of Components:

Component A

Viscosity, Brookfield No. 2 Spd 5 rpm	= 12-18 poises
Ash	= 8.2%-8.4%

Component B

Viscosity, Brookfield No. 2 Spd 5 rpm	= 14-20 poises
Alkalinity Eq/100 g	= 0.34
Water	= 1.0%

Gel Time:

Equal Volumes A and B in a 60 gram mass = 12 minutes

Physical Properties of a 1/8 inch Cast Sheet of the Binder:

A 1/8 inch thick cast sheet of the binder when cured at 77°F for 7 days followed by 24 hours at 158°F shall have the following properties at 77°F:

Tensile strength, psi, when tested according to ASTM D638-60T (test rate of 0.2 inches per minute using a C die described in ASTM D 412-61T except the narrow width shall be 0.5 inch)	1000 minimum
Tensile elongation, percent under the test method specified above	75 minimum
Shore D Hardness	50 minimum
Percent by weight gain in water (immersion for 7 days @ 77°F)	0.8 maximum

Other Physical Properties of Binder After Curing 7 Days at 77°F:

Flexural Creep in inches at -6°F (California Test Method 419A) 7 days	0.0140 minimum

Compressive Strength, psi, when 1 part by volume of binder is mixed with 4 parts by volume of Ottawa Sand (ASTM C-190) and cured in 2 inch diameter castings 4 inches long	2000 minimum

Labeling:

Each filled container shall be labeled as described below with the title of this specification, the manufacturer's name, lot or batch number, State Specification number and date of packaging. Components A and B shall be properly designated as such on each container following the title and number of this specification. The labels for both Components A and B shall have the following statements regarding directions for use and warning.

Directions for Use

Just before use thoroughly mix one part by volume of Component A with one part by volume of Component B. If the aggregate is to be incorporated into the binder add the clean and dry aggregate immediately after Components A and B are thoroughly mixed. Do not mix more material than can be used within 15 minutes from the time mixing operations are started. The amount of aggregate used will depend upon its size. No more aggregate should be used than that which will provide an epoxy mortar or concrete which will wet the portland cement concrete substrate to which it is applied.

When used for a thin surface overlay, the mixed binder shall be applied uniformly at the rate of 0.3-0.4 gallons per square yard and a uniform application of surfacing sand or grits applied in a quantity sufficient to result in no bare spots.

Warning

This material will cause severe dermatitis if proper precautions are not followed. Do not let it come in contact with the skin or eyes. Use gloves and protective creams on the hands. If contact with the skin occurs, wash thoroughly with soap and water. If any gets in the eyes flush for 10 minutes with water and secure immediate medical attention. Do not try to remove this material from the skin with solvents.

Surface Preparation:

The portland cement concrete shall be thoroughly cleaned by sandblasting before application of the epoxy binder or epoxy mortar.

Aggregate for Thin Surface Overlays:

Aggregate shall be a clean, dry and tough (not brittle or friable) natural silica sand free of mica and other deleterious materials and conforming to the following requirements. No less than 90 percent of the aggregate shall have a minimum Moh's hardness of 7.0 and not more than five percent of the aggregate shall have a Moh's hardness of less than 6.0. The color shall be such that the finished surfacing will match the coloring of finished portland cement concrete.

Packaging:

Components A and B shall be packaged in 5-gallon cylindrical steel containers. The steel containers shall be new and not less than 24 gauge and otherwise meet Interstate Commerce shipping standards and shall be well sealed with ring seals and lug type crimp lids to prevent leakage. If a lining is used in the steel containers it shall be of such character as to resist any action by the adhesive components. It shall be incumbent upon the vendor to replace any material which is unfit for use for any reason other than improper handling by the user. Material showing any separation of resins which fails to redissolve when warmed to 75°F for one week shall be replaced by the manufacturer.

STATE SPECIFICATION 682-80-45

AROMATIC PETROLEUM OIL MODIFIED
EPOXY RESIN BINDER

October, 1968

Classification:

This epoxy resin adhesive is not designed for use in the bonding of fresh portland cement concrete to old portland cement concrete. This epoxy binder is intended to be used with selected aggregates to form a quick setting epoxy mortar or concrete for use in the repair of pot holes or spalled areas on concrete structures or as a binder for thin extensive surface overlays on portland cement concrete highway surfaces and bridge decks. This binder was designed to have sufficient creep or stress relief at sub-zero temperatures to provide an epoxy mortar or concrete which would not rupture the adjacent portland cement concrete in tension because of the differences in the thermal coefficients of expansion of the epoxy mortar and portland cement concrete. The epoxy binder in this specification turns to a brown color on exposure to sunlight. Where a permanent gray color is desired, State Specification 681-80-46 should be specified.

Composition:

Component A	Parts by Weight*
Orthocresol Glycidyl Ether	130.4
Epoxy Resin[1]	739.1
Alkyl substituted polynuclear aromatic oil[2]	51.8
Titanium Dioxide, TT-P-442, Types III or IV	37.4
Component B	
N-Aminoethyl piperazine[4]	216.7
Nonylphenol[5]	216.7
Alkyl substituted polynuclear aromatic oil[2]	392.7
Carbon Black	0.4
Colloidal Silica[3]	12.0

All pigments must be properly dispersed so that there is no evidence of unwetted particles or of hard settling. Any settling must be readily dispersed with a paddle.

All tests shall be performed in accordance with Test Method No. Calif. 430

*Yield approximately 98 gallons per component. The vendor is cautioned not to entrap air in these components which is not readily released on standing.

Names of materials meeting the requirements listed below will be supplied upon request by the Materials and Research Department of the Division of Highways

[1]Viscosity, 100-160 poises at 25°C; epoxide equivalent 180-200, Color (Gardner), 3 maximum; manufactured from epichlorohydrin and bisphenol A. No reactive diluent shall be present.

[2]High boiling, alkyl substituted polynuclear aromatic oil. Weight per gallon at 77°F, 9.00 - 9.15; flash point, °F, Pensky Martens Closed Cup (ASTM E134), 350 - 390; viscosity SU at 100°F, 90 - 120; mixed aniline point (ASTM D-1012), °F, 72 maximum; color, Gardner, 1933, 12 maximum; viscosity, Gardner-Holdt at 77°F, A-C; percent aromatic, 95 minimum.

Distillation Range

Percent Distilled	°F
I BP	580 Min.
5	610-640
10	620-660
50	650-700
90	680-740

[3]SiO_2 (moisture-free basis), 99% minimum; refractive index, 1.46; surface area, 175-225 square meters per gram; particle size 0.015 microns; pH (4% aqueous dispersion), 3.5-4.2; pour density, 2.3 lbs./cu.ft. maximum; free moisture at 105°C, 1.0% maximum.

[4]Color (APHA) 50 maximum; amine value 1250-1350 based on titration which reacts with the 3 nitrogens in the molecule; appearance clear and substantially free of suspended matter.

[5]Color (APHA) 50 maximum; hydroxyl number 245-255; distillation range, °C. at 760 mm first drop 295 minimum, 5% 298 minimum, 95% 325 maximum; water, % (K.F.) 0.05 maximum.

Properites of Components:

Component A

Viscosity, poise, 77°F, Brookfield No. 2 Spindle, 10 rpm	13-23
Ash, percent by weight	4.0 maximum
Epoxide equivalent on vehicle	190-212
Weight per gallon, pounds at 77°F	9.6 minimum

Component B

Viscosity, poise, 77°F, Brookfield, Helipath A Spindle, 5 rpm	15-25
Ash, percent by weight	1.5 maximum
Amine value on vehicle	328-354
Shear Ratio	2.9 minimum
Weight per gallon, pounds at 77°F	8.3 minimum

Infra-red curves for the extracted vehicles of Components A and B must match those on file in the Materials and Research Department of the Division of Highways.

Gel Time, minutes	10-18

Physical Properties of a 1/8 inch Cast Sheet of the Binder at 77°F.

Tensile strength, psi	500 minimum
Tensile elongation, percent	50 minimum
Shore D Hardness	50 minimum

Characteristics of Adhesive when equal parts by volume of Components A and B are mixed and cured for 7 days at 77 ± 3°F.

Bond Strength	200 minimum

Labeling:

Each filled container shall be labeled as described below with the title of this specification, manufacturer's name, lot or batch number, State Specification number and date of packaging. Components A and B shall be properly designated as such on each container following the title and number of this specification. The labels for both Components A and B shall have the following statements regarding directions for use and warnings:

Directions for Use

Immediately prior to mixing, each component (Components A and B) shall be thoroughly redispersed by stirring. Do not use the same paddle to stir Component A as is used to stir Component B. Any material that cannot be readily redispersed shall be rejected. After redispersment, one volume from Package A shall be mixed with one volume from Package B until a uniform gray color is obtained.

When used for a thin surface overlay, the mixed binder shall be applied uniformly at the rate of 0.3-0.4 gallons per square yard. Within five minutes after application of the binder a uniform application of the specified sand or grits shall be applied in a quantity sufficient to result in no bare spots.

Warning

This material will cause severe dermatitis if proper precautions are not followed. Do not let it come in contact with the skin or eyes. Use gloves and protective creams on the hands. If contact with the skin occurs, wash thoroughly with soap and water. If any get in the eyes flush for 10 minutes with water and secure immediate medical attention. Do not try to remove this material from the skin with solvents.

Surface Preparation:

The portland cement concrete shall be thoroughly cleaned by sandblasting before application of the epoxy binder or epoxy mortar.

Aggregate for Thin Surface Overlays:

Aggregate shall be clean, dry, tough and shall conform to the hardness and grading requirements specified.

Packaging:

Components A and B shall be packaged in 5-gallon cylindrical steel containers. The steel containers shall be new and not less than 24 gauge and otherwise meet Interstate Commerce shipping standards and shall be well sealed with ring seals and lug type crimp lids to prevent leakage. If a lining is used in the steel containers it shall be of such character as to resist any action by the adhesive components. It shall be incumbent upon the vendor to replace any material which is unfit for use for any reason other than improper handling by the user. Material showing any separation of resins which fails to redissolve when warmed to 75°F for one week shall be replaced by the manufacturer.

BINDER (ADHESIVE), EPOXY RESIN BASE,
ALKYLBENZENE EXTENDED

STATE SPECIFICATION 681-80-46

Classification:

This specification covers a 2-component epoxy resin base, flexible, binder material for anti-skid resinous overlays and for preparing epoxy resin concretes and mortars to repair spalls and other defects in portland cement concrete pavements and concrete structures. The binder shall have a white A epoxy component and a black B curing agent component, each packaged separately.

Composition

Component A	Percent by Weight
Epoxy Resin[1]	73.40
Alkylbenzene[2]	8.16
Titanium Dioxide, TT-P-442, Type III or IV	6.32
Talc[3]	3.73
Colloidal Silica[4]	0.22
Dinonyl phenol, distilled grade[5]	8.16
Dow Corning Antifoam Q	0.01

Component B	
Alkylbenzene[2]	24.72
Talc[3]	9.65
Colloidal Silica[4]	0.51
N-Aminoethyl piperazine[6]	20.18
Nonyl phenol[7]	20.18
Dinonyl phenol, distilled grade[5]	24.72
Furnace Black	0.03
Dow Corning Antifoam Q	0.01

[1]Viscosity, 5-7 poises at 25°C.;epoxide equivalent 175-195; Color (Gardner), 5 maximum; manufactured from epichlorohydrin and bisphenol A. The reactive diluent shall be butyl glycidyl ether.

[2]This is a snythetic alkylbenzene in which the alkyl side chain is highly branched and contains, on the average, 13 carbon atoms. It shall have the following properties:

Weight per gallon in pounds at 77°F	7.0-7.4
Flash, Cleveland Open Cup, °F	280 min.
Color, (APHA)	25 max.

[2]Continued

Viscosity at 100°F., Centistokes (ASTM D88 and D446)	8.0-8.4
Bromine Number (grams bromine/100 grams oil)	0.03 max.
Sediment and water, Vol. %	Nil
Distillation Temperature, °F., ASTM D 447	
5% Recovered	547-557
95% Recovered	599-609

[3]Percent passing U. S. No. 325 sieve, 100; specific surface, 2.3-2.4 square meters per gram; maximum particle size, 12 microns; oil absorption (Gardner-Coleman), 10-11 ml. per 20 grams; consistency (40 percent suspension in linseed oil), 94-97 KU; fineness in oil (Hegman), 6 minimum.

[4]SiO_2 (moisture-free basis), 99% minimum; refractive index, 1.46; surface area, 175-225 square meters per gram; particle size 0.015 microns; pH (4% aqueous dispersion), 3.5-4.2; pour density, 2.3 lbs./cu.ft. maximum; free moisture at 105°C., 1.0% maximum.

[5]Color, Gardner (ASTM D 1544), 3 maximum; weight per gallon in pounds at 77°F., 7.5-7.7; hydroxyl number (acetylation), 145-165; refractive index at 25°C., n_d = 1.496-1.506; boiling range, °C at 760 mm, 5-10% at 325.

[6]Color (APHA) 50 maximum; amine value 1250-1350 based on titration which reacts with the 3 nitrogens in the molecule; appearance clear and substantially free of suspended matter.

[7]Color (APHA) 50 maximum; hydroxyl number 241-255; distillation range, °C at 760 mm first drop 295 minimum, 5% 297 minimum, 95% 325 maximum; water, % (K.F.) 0.05 maximum.

All pigment shall be properly dispersed so that there is no evidence of settling. Any settling shall be readily dispersed with a paddle.

All tests shall be performed in accordance with Test Method No. Calif. 429.

<u>Characteristics of Compounded Adhesives</u>:

Component A

Weight per gallon, pounds at 77°F	9.4 min
Pigment, percent by weight	9.8 min.
Viscosity, poise, Brookfield	6-12
Titanium Dioxide, percent by weight of pigment	57.0 min.
Epoxide equivalent	214-238

Component B

Weight per gallon, pounds at 77°F.	8.0 min.
Pigment, percent by weight	9.7 min.
Viscosity, poise, Brookfield	10-20
Amine Value on vehicle	281-303

Infra-red curves of the vehicle components shall match those on file in the Materials and Research Department of the Division of Highways.

Characteristics of Adhesive when equal parts by volume of Components A and B are mixed and cured for 7 days at 77° ± 3°F.

Bond Strength, psi	200 min.
Tensile Strength, psi	350 min
Tensile Elongation, percent	50 min.
Shore D Hardness	30 min.
Low Temperature Creep	0.020 inches at 24 hrs. 0.040 inches at 7 days.
Color	Approximately that of Colors Nos. 36373 to 36492 of Federal Standard No. 595.
Gel Time of Adhesive	15-20 minutes

Directions for Use

Components A and B shall be at a temperature between 65°F. and 85°F. at the time of mixing.

The contents of the separate packages containing Components A and B shall be thoroughly stirred before use to redisperse the pigments. The same paddle shall not be used to stir Component A as is used to stir Component B. The adhesive shall be mixed by blending one part by volume of Component A with one part by volume of Component B and stirring thoroughly until a uniform gray color is obtained without visible black or white streaks. No more material shall be mixed than can be used within 10 minutes from the time mixing operations are started. Clean, dry aggregate shall be used to produce the desired mortar or concrete. The prepared mortar shall wet the surface to which it is applied to provide proper adhesion. The use of an excessive amount of aggregate which produces a dry mortar shall be avoided.

Equipment and tools shall be cleaned with solvent before the adhesive has set.

Any heating of epoxy adhesive shall be done by application of indirect heat.

STATE OF CALIFORNIA—TRANSPORTATION AGENCY RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

EXPERIMENTAL FAST SETTING EPOXY RESIN BINDER

FORMULA AC-51

March, 1969

Classification

This epoxy resin adhesive is not designed for use in the bonding of fresh portland cement concrete to old portland cement concrete. Epoxy binder Formula AC-51 is intended to be used with selected aggregates to form a quick setting high strength, rigid, color stable epoxy mortar or concrete for use in the repair of pot holes or spalled areas on concrete structures. This epoxy is especially suited for cold weather repair work in the 40°F to 50°F range and is suitable for use in areas subject to moderate freeze-thaw action. The adhesive is to be used in the ratio of two parts by volume of Component A to one part by volume of Component B.

Composition

Component A	Parts by Weight
Epoxy resin, Shell 828 or equal	100
Alkylbenzene, Chevron Alkylate 31	10
Nonyl phenol[1]	9.3
Titanium Dioxide TT-P-442 Type III or IV	2.0
Dow Corning Anti-Foam Q	.01

Component B	
Polymercaptan Diamond Shamrock Dion 3-800 LC (Deodorized)	40.0
DMP 30 - 2,4,6-Tri(Dimethyl aminomethyl phenol)[2]	2.0
N-aminoethyl piperazine[3]	16.6
Furnace Black	0.03
Dow Corning Anti-Foam Q	0.01

[1] Color (APHA) 50 maximum; hydroxyl number 241-255; distillation range, °C. at 760 mm first drop 295 minimum, 5% 297 minimum, 95% 325 maximum; water, % (K.F.) 0.05 maximum.

[2] Formula weight 265; specific gravity at 25°/25°C., 0.973; refractive index, 1.514 at 25°C; distillation range 96% at 130-160°C (0.5-1.5 mm); flash point, Tag Open Cup. 300°F. minimum, water content, 0.06% maximum.

[3]Color (APHA) 50 maximum; amine value 1250-1350 based on titration which reacts with the 3 nitrogens in the molecule; appearance clear and substantially free of suspended matter.

Physical Properties

Viscosity

Component A poise	25 - 45
Component B poise	35 - 55
Pot Life, minutes, 6 oz. mass	6 - 10
Compression Strength (4 to 1 Ottawa sand-binder mix)	
Minimum psi after one week at 77°F	10,000

Packaging

Components A and B shall be packaged separately in steel containers having lug type crimp lids with ring seals not larger than 5 gallons in volume. The steel containers shall be new and not less than 24 gauge and otherwise meet Interstate Commerce shipping standards, and shall be well sealed to prevent leakage. If a lining is used in the steel containers, it shall be of such character as to resist any action by the adhesive components. It shall be incumbent upon the vendor to replace any material which is unfit for use for any reason other than improper handling by the user. Material showing a permanent increase in viscosity or hard settling not readily redispersed with a paddle shall be replaced by the manufacturer.

Labeling

Each filled container shall be labeled with the title of this specification, the manufacturer's name, lot or batch number, State Specification number, and date of packaging. Components A and B shall be properly designated as such on a label on the side of each container following the title and number of this specification. The proper component designation shall also be placed on each lid.

The labels for both Components A and B shall have the following statements regarding directions for use and warnings:

Directions for Use

The contents of the separate packages containing Components A and B must be thoroughly stirred before use to redisperse the pigments. Do not use the same paddle to stir Component A as is used to stir Component B. Just before use thoroughly mix two parts by volume of Component A with one part by volume of Component B until a uniform gray color is obtained. Add clean, dry aggregate immediately after Components A and B are thoroughly mixed. Since this binder sets rapidly it is mandatory that the epoxy mortar or concrete be placed as soon as possible. The useful work life of the mortar will depend on temperature but will be about 10-15 minutes at 75°F. Prime all surfaces with mixed epoxy. This may be done with some epoxy that is withheld before aggregate is added. The use of an excessive amount of aggregate which produces a dry mortar must be avoided.

The use of solvents or thinners will not be permitted except for clean-up of equipment after use. If the epoxy components are too viscous, due to cold weather, then indirect heating of each component to not greater than 90°F will be permitted.

Warning

This material will cause severe dermatitis if proper precautions are not followed. Do not let it come in contact with the skin or eyes. Use gloves and protective creams on the hands. If contact with the skin occurs, wash thoroughly with soap and water. If any gets in the eyes, flush for 10 minutes with water and secure immediate medical attention. Do not attempt to remove this material from the skin with solvents.

Surface Preparation

Unsound concrete shall be removed before repair. PCC shall be thoroughly cleaned by sandblasting before application of epoxy mortar or concrete. Air supply to sandblast unit shall be properly trapped to remove excess oil and water.

STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

5900 FOLSOM BLVD., SACRAMENTO 95819

EXPERIMENTAL FAST SETTING EPOXY RESINOUS OVERLAY

FORMULA AC82

February, 1969

Classification

This system is a two component alkylbenzene extended epoxy resin and fast setting hardener for use in antiskid resinous overlays and repair of minor spalls and pot holes in PCC where maximum compressive strength is not required. This binder is especially suitable for repair work in the 40°F to 50°F range, and also in freeze-thaw environments. This system has high flexibility, color stability, tensile strength, and higher compressive strength than existing oil extended epoxy systems. This adhesive is to be used in the ratio of one part by volume of Component A to one part by volume of Component B.

Composition

Component A	Parts by Weight
Epoxy resin, Shell 828 or equal	100.00
Nonyl phenol[1]	19.70
Alkylbenzene, Chevron Alkylate 31	19.70
Colloidal Silica, Cab-O-Sil M5	1.50
TiO_2, TT-P-442, Type III or IV	1.62
Dow Corning, Anti Foam Q	0.01

Component B	
Polymercaptan Dion 3-800 LC (Deodorized) Diamond Shamrock	40.00
N-Aminoethylpiperazine[2]	17.00
DMP 30 (2-4-6 Tridimethylaminomethyl phenol)[3]	2.00
Witco Furnace Black	0.03
Alkylbenzene, Chevron Alkylate 31	34.52
Nonyl phenol[1]	34.52
Colloidal Silica, Cab-O-Sil M5	1.75
Dow Corning Anti-foam Q	0.01

[1]Color (APHA) 50 maximum; hydroxyl number 241-255; distillation range, °C at 760 mm first drop 295 minimum, 5% 297 minimum, 95% 325 maximum; water, % (K.F.) 0.05 maximum.

[2]Color (APHA) 50 maximum; amine value 1250-1350 based on titration which reacts with the 3 nitrogens in the molecule; appearance clear and substantially free of suspended matter.

[3]Formula weight 265; specific gravity at 25°/25°C, 0.973; refractive index, 1.514 at 25°C; distillation range 96% at 130-160°C (0.5-1.5 mm); flash point, Tag Open Cup, 300°F minimum; water content, 0.06% maximum.

Physical Properties

Viscosity - Brookfield Helipath Spindle A at 77°F.

Component A	15-35 poise at 5 rpm	
Shear Ratio	$\frac{2.5 \text{ rpm}}{0.5 \text{ rpm}}$	1.3 minimum
Component B	15-35 poise at 5 rpm	
Shear Ratio	$\frac{2.5 \text{ rpm}}{0.5 \text{ rpm}}$	1.5 minimum

When Mixed 1:1 by Volume

Pot Life, 4 oz. mass at 77°F	10 - 15 minutes

On 1/8" cast sheet, cured 18 hours at 77°F + 5 hours at 158°F.

Tensile Strength	900 psi minimum
Elongation	70% minimum
Shore D	50 minimum

Tensile Bond to Concrete

Minimum 200 psi using a 4-1 Ottawa Sand-Binder Mortar, 1/4-inch thick bonded to a concrete block and cured 7 days at 77°F. Strength measured according to Calif. Method 420 A.

Packaging

Components A and B shall be packaged separately in steel containers having lug type crimp lids with ring seals not larger than 5 gallons in volume. The steel containers shall be new and not less than 24 gauge and otherwise meet Interstate Commerce shipping standards, and shall be well sealed to prevent leakage. If a lining is used in the steel containers, it shall be of such character as to resist any action by the adhesive components. It shall be incumbent upon the vendor to replace any material which is unfit for use for any reason other than improper handling by the user. Material showing a permanent increase in viscosity or hard settling not readily redispersed with a paddle shall be replaced by the manufacturer.

Labeling

Each filled container shall be labeled with the title of this specification, the manufacturer's name, lot or batch number, State Specification number, and date of packaging. Components A and B shall be properly designated as such on a label on the side of each container following the title and number of this specification. The proper component designation shall also be placed on each lid.

The labels for both Components A and B shall have the following statements regarding directions for use and warnings:

Directions for Use

The contents of the separate packages containing Components A and B must be thoroughly stirred before use to redisperse the pigments. Do not use the same paddle to stir Component A as is used to stir Component B. To mix the adhesive, blend one part by volume of Component A with one part by volume of Component B and stir thoroughly until a uniform gray color is obtained without visible black or white streaks. Do not mix more material than can be used within 10 minutes from the time mixing operations are started. Use clean, dry aggregate to produce the desired mortar or concrete. Prime all surfaces with mixed epoxy. This may be done with some epoxy that is withheld before aggregate is added. The use of an excessive amount of aggregate which produces a dry mortar must be avoided.

When applying resinous overlay, the sand must be sprinkled in the epoxy film not later than 10 minutes after epoxy is applied to the road surface.

The use of solvents or thinners will not be permitted except for clean-up of equipment after use. If the epoxy components are too viscous, due to cold weather, then indirect heating of each component to not greater than 90°F will be permitted.

Warning:

This material will cause severe dermatitis if proper precautions are not followed. Do not let it come in contact with the skin or eyes. Use gloves and protective creams on the hands. If contact with the skin occurs, wash thoroughly with soap and water. If any gets in the eyes, flush for 10 minutes with water and secure immediate medical attention. Do not attempt to remove this material from the skin with solvents.

Surface Preparation

Unsound concrete shall be removed before repair. PCC shall be thoroughly cleaned by sandblasting before application of resinous overlay or epoxy mortar. Air supply to sandblast unit shall be properly trapped to remove excess oil and water.